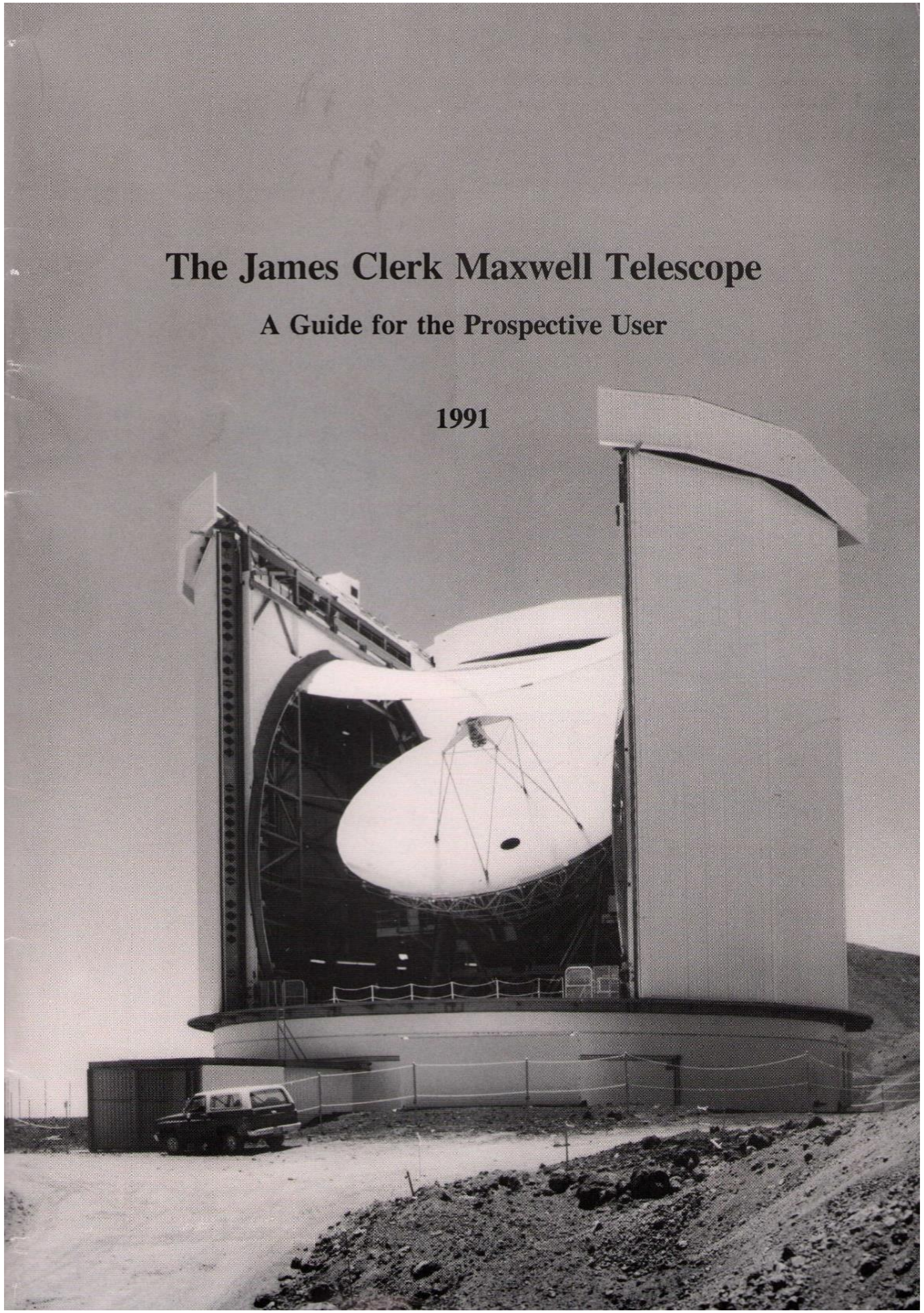
The James Clerk Maxwell Telescope

A Guide for the Prospective User

1991



The James Clerk Maxwell Telescope: A Guide for the Prospective User

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Preface

The 15-m diameter JCMT is the largest telescope in the world capable of operating throughout the millimetre and sub-millimetre wavebands. Situated close to the summit of Mauna Kea, Hawaii, its location is the best of the established major observatory sites. The telescope is managed by the Royal Observatory Edinburgh, and funded jointly by the Science and Engineering Research Council (United Kingdom), the National Research Council (Canada), and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (The Netherlands). The site is provided by the University of Hawaii. Local technical, astronomical and administrative support is provided by the Joint Astronomy Centre, in Hilo, Hawaii. Major developmental initiatives are undertaken by various technical groups in the participating nations.

Operating policies for the telescope are set by the JCMT Board which receives recommendations from the JCMT Users' Committee on all user-related issues. Therefore, users that wish to comment on any aspect of telescope operation are urged to express their concerns to their nearest Users' Committee member.

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ERRATUM

Appendix PATT 5 (page 37+7), foot of page. Closing dates for PATT applications are:

Semester	Closing date
February - July	30 September
August - January	31 March

1 INTRODUCTION AND SUMMARY

This document is designed to aid those who wish to prepare proposals for astronomical observations with the James Clerk Maxwell Telescope (JCMT). It contains information on the telescope and its performance, on the frequency dependence of atmospheric transmission, and on receiver and spectrometer specifications. Data on forthcoming and planned facilities are included. The procedure and deadlines for the submission of proposals are given, together with relevant addresses and other information.

At the time of writing semester 'T' is in progress, and proposals are being accepted until September 30, 1991 for observations to take place in semester 'V', which occupies the months February 1992 through July 1992 inclusive[1]. During this period, spectral line receivers covering the λ1.3mm (220–280 GHz), λ0.9mm (320–375 GHz) and parts of the λ0.6mm (specifically, around 461 and 492 GHz, to access the CO J=4–3 and CI $^3P_1$–$^3P_0$ transitions) windows should be available on a 'common-user' basis. Also, by continuing arrangement with Reinhard Genzel's group at the Institut für extraterristrische Physik 'Receiver G' provides the capability to observe narrow windows in the 690 and 800 GHz regions, offering in particular the CO J=6–5 and 7–6 lines and the CI $^3P_2$–$^3P_1$ transition. With the exception of the 461/492 GHz receiver, acousto-optical spectrometers provide the backends for these receiver systems; an autocorrelation spectrometer should also be in routine use early in 1992.

Continuum photometry and mapping at wavelengths between λ2mm and λ350μm (150–870 GHz) using the UKT14 bolometer system will be possible. In addition, the ability to make continuum polarization measurements will exist.

Much of the information herein has appeared at some time or another in the newsletter of the JCMT[2], but I have have attempted to assemble here in one place all the information which a user may need to make a sensible proposal. Nevertheless, the JCMT and its equipment continue to improve, and the data given should be regarded as providing an approximate guide only. The present intent is that this report shall be kept as current as possible, and copies distributed to users upon request. I would appreciate feedback on items which are, or should be, covered in this report.

A number of individuals have contributed substantially to this document, notably Adrian Russell, Graeme Watt, Göran Sandell, Richard Hills, Richard Prestage, Hugh Gibson, Peter Hekman, and Carol Bergeron.

2 TELESCOPE AND SITE PROPERTIES

2.1 Basics

The JCMT has an alt-azimuth mounting, and is housed in a carousel corotating with the antenna. To protect the antenna and associated equipment from the elements, the carousel has both large doors and a sliding roof, which are stowed during operation. Under normal observing conditions,

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[1] For administrative reasons, the intervening semester ('U') has been shortened by one month. Subsequent semesters will again be six months long. See section 7.1.

[2] Formerly '*Protostar*', now renamed '*JCMT-UKIRT Newsletter*'; in this document I shall simply refer to it as the '*Newsletter*' for brevity

a membrane transparent to mm- and submm-waves is in place, protecting the telescope from exposure to the sun, wind, and dust.

The JCMT antenna is located at: longitude(west) 155° 28′ 47″, latitude 19° 49′ 33″, at an altitude of 4092m. The local time is Hawaiian Standard (HST; = UTC − 10 hours) which is in effect throughout the year. The antenna has a lower elevation limit of 5°, and sources may not be tracked beyond about 87°. The current azimuth velocity limit is about 0.6°/sec; this is being increased as difficulties with the carousel drive motors are resolved.

2.2 Antenna Surface

The continuing improvement of the antenna primary reflector surface is of fundamental importance. The adjustments necessary to obtain a perfect paraboloid are measured by recording the beam pattern at two focus settings using a 94 GHz source located in the UKIRT dome (*i.e.*, within the near field). Recent measurements with this technique show that the rms fluctuations of the antenna surface are about 30μm; this is the result of small-scale (fractions of a panel in size) errors having an rms of 24μm, and large-scale (typically about 5m) structure with deviations of about 16μm. In time it should be possible to improve the surface accuracy well beyond this value; however it is believed that a clear understanding of the behaviour of the telescope in response to temperature fluctuations is now required; progress is ongoing in this area.

2.3 Pointing and Tracking

The pointing model of the telescope is derived from continuing extensive radio measurements combined with boresight observations of bright stars to provide basic structural parameters. The more recent pointing models incorporate azimuth track irregularities and give pointing to about 2 arcsec (rms) in both azimuth and elevation. The alignment with respect to the optical axis of each receiver is carefully checked on installation. Nevertheless, during an observing run it is advisable to check the pointing fairly frequently, and some allowance (say, 20%, and probably more for point source observations, especially at the higher frequencies) for such measurements should be made when calculating the total time required for a program.

The tracking accuracy of the antenna has not been fully investigated, but appears to be better than 1 arcsec over periods of an hour or so. However, at high elevations (above about 80°), tracking may become less reliable due to the rapid movement of the source in azimuth, particularly during position-switched observations.

2.4 Beam Path

Incoming radiation is directed by an accurately-figured secondary mirror into the receiver cabin, which is located below the primary mirror surface between the elevation bearings, at the Cassegrain focus. From here the optical path goes by means of a tertiary mirror to one or other of the possible receivers, which are mounted on racks within the cabin or on one of the Nasmyth foci platforms. The focal length is modified by using a hyperboloid (rather than flat) tertiary mirror for receiver systems outside the cabin. The tertiary mirrors are mounted on a turret structure which is under computer control to permit automatic redirection of the beam path to one or other of the receiver positions.

2.5 Chopping Secondary Mirror

For continuum photometry, pointing and focus determinations, and some spectral line observations (including those with 'Receiver G'), the secondary mirror is 'chopped', or nutated, at a frequency and amplitude ('throw') which can be chosen by the user. This provides a detected signal which is the difference between the signals from the sky at the source and reference (chopped) positions, and from which most of the atmospheric background variations have then been removed. It is common practice also to position-switch the telescope during 'chopped' observations such that the source appears alternately in the signal and reference beams.

Most photometry and many spectral line observations are carried out using chopping in azimuth. However, in some cases it will be desirable to chop, say, in Right Ascension and thus ensure that the reference point is always in the same position relative to the source of interest. Recent changes to the secondary mirror microcomputers should permit observations of this type, and allow the user to choose any position angle for the secondary mirror chop direction. It should also be possible to drive the mirror axes in such a way as to provide circular, and essentially any other patterns of motion.

In principle one should choose the greatest chop frequency, and smallest chop throw practical to obtain good results. The default chopping frequency presently in use for most continuum measurements is 7.8125 Hz, which gives reasonable atmospheric cancellation and good mechanical performance for at least the shorter chop throws (1–2 arcmin). Chopped ('beamswitched') spectral line observations use a much lower chop frequency, usually 1 Hz.

2.6 Frequency-Dependent Telescope and Atmospheric Parameters

At present, only a few of the parameters of the antenna and the atmosphere have been accurately determined, although there is an ongoing program to obtain the necessary values. A summary of the best available numbers to date is given in Table 1, which includes the antenna efficiencies, beamwidth, atmospheric transmission, and percentage of 'good' nights at a number of representative frequencies. Where appropriate, those numbers that have been obtained through calculation only are enclosed in parentheses.

Table 1: Overview of Telescope and Atmospheric Parameters

Frequency (GHz)	Wavelength (μm)	Efficiency†		η_{fss}	Beamwidth (arcsec)	Atmos. trans.	Nights (%)
		Aperture	Beam				
150	2000	(0.66)	—	—	28	0.97	90
230	1300	(0.63)	0.65	0.80	21	0.96	90
345	870	(0.56)	0.55	0.75	14	0.88	70
492	610	(0.46)	0.25	—	12	0.43	30
690	435	(0.32)	0.24	—	8	0.38	30
870	345	(0.21)	$\sim$ 0.1	—	6	0.44	30

†Aperture efficiency calculated assuming the rms surface accuracy is 30μm

2.6.1 Antenna Efficiencies

Using the figure of 30μm for the measured surface accuracy as a basis, the the aperture efficiencies η_a given in Table 1 have been calculated using the standard (Ruze) formula, with corrections to the theoretical aperture efficiency for losses and blockage. For the most part η_a has not actually been measured for the receivers in use on the JCMT. The most recent values of the main-beam efficiency, where they have been reliably determined are included in Table 1. The beam efficiency is in any case difficult to quantify in practice, since the response of the antenna to extended sources depends on the source structure, as well as the illunination of the antenna by the particular receiver being used. The efficiency for forward spillover and scattering, η_{fss} (see Section 3.9), is also given in the table for those cases in which a measurement has been made.

2.6.2 Telescope Beam Pattern

The half-power beamwidths given in Table 1 are the results of measurement and extrapolation. At the lower frequencies the beam shape is well determined and an approximately circularly symmetric Gaussian. At the shortest wavelengths at which it has been determined, *i.e.*, 350μm, the maximum amplitude of the error beam ('sidelobes') is at about 10% of the main beam, if the telescope is correctly focussed. The MPE group have found that at the highest frequencies it becomes necessary to model the beam with a three-component structure; only about half the power is in the central 'beam'.

2.6.3 The Atmosphere above the JCMT

Figure 1 shows the atmospheric transmission at the zenith above Mauna Kea as a function of frequency for three different values of precipitable water vapour pressure. Strong absorption lines of atmospheric oxygen and water vapour divide the millimetre and submillimetre band into sharply defined 'windows'. At the higher frequencies, the atmosphere allows at most rather less than half the incident radiation to reach the telescope. Representative values of the atmospheric transmission at the zenith are given in Table 1 also, as a guide to allow the calculation of atmospheric attenuation and contribution to system temperature at the frequencies listed. Bear in mind that conditions are highly variable on many occasions, that the given frequencies relate to the peaks of the atmospheric transmission curve, and that the optical depth along a given line of sight varies approximately as cosec(elevation).

The data obtained by the Caltech Submillimeter Observatory radiometer which monitors the atmosphere by performing frequent skydips became available to observers at the JCMT at the end of 1989. Although this operates at 225 GHz it provides a good on-the-spot record of changes in the opacity at all frequencies. Changes of a factor of two or more within an hour do not seem to be uncommon. It also appears that the opacity at 225 GHz can be directly scaled to the opacity at other frequencies; for instance $\tau_{690} \sim 23\tau_{225}$ (van der Veen, private communication). An example of the variation of the zenith optical depth at 225 GHz during a recent 'rather good' period is given in Figure 2.

In the final column of Table 1, a very subjective estimate is given of the percentage of nights on which observations may reasonably be expected to be rewarding at the given frequency; hence

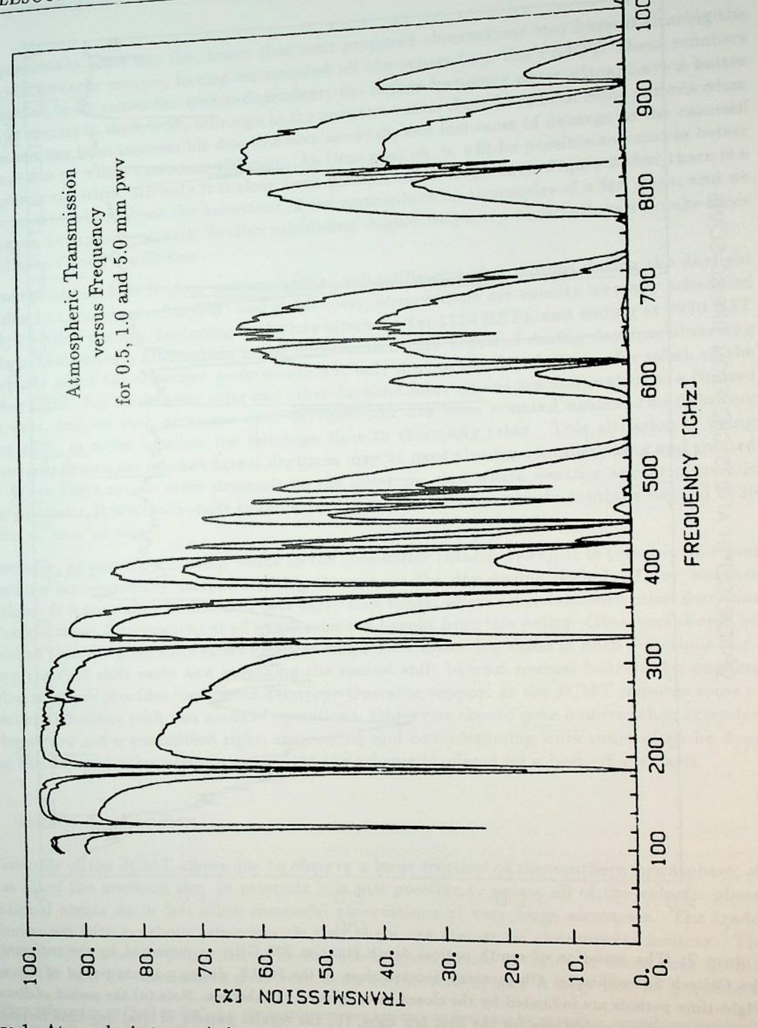

Figure 1: Atmospheric transmission as a function of frequency in the submillimetre window for three different water vapour pressures (1mm pwv is a 'good' night, 0.5mm pwv 'exceptional').

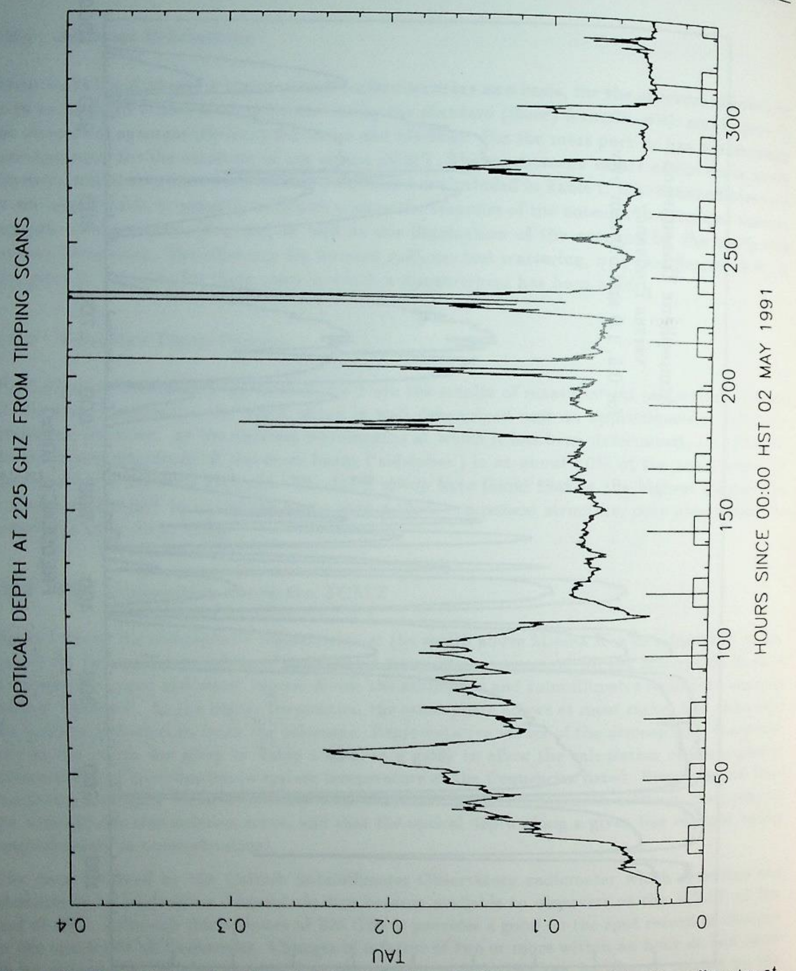

Figure 2: The variation of zenith optical depth (tau) at 225 GHz, as measured by the radiometer at the Caltech Submillimeter Observatory, located close to the JCMT, during a recent period of two weeks. Night-time periods are indicated by the closed rectangles on the abscissa. Note (a) the period of disturbed upper-atmosphere conditions for the first few days, (b) the regular pattern of local day-time increases in water vapour content during the second week, (c) the general slow trend in night-time opacity during this period, and (d) the absence of local daytime disturbances for a period of two days around the middle of the period. The equivalent mm of water vapour pressure may be obtained approximately by multiplying the optical depth by 12. Figure courtesy of Caltech Submillimeter Observatory.

this represents in some way the chance that your proposed observations may have of clearing the last hurdle towards success, having surmounted all the others (*e.g.* the PATT). These numbers are expected to be somewhat season-dependent; *i.e.* higher-frequency observations have a better chance of success in the winter, although in the past two years, there have been some periods when the summit has been inaccessible due to heavy snowfall, and instances of damage to the carousel structure due to winds exceeding 100 mph. As time goes on, it will be possible to provide better atmospheric statistics. Already it is clear from examples such as given in Figure 2 that there is a certain predictability about the behaviour of the atmosphere on timescales of a few days, and we have begun to experiment with 'flexibly scheduling' higher-frequency observations to make more efficient use of good conditions.

Because the atmosphere is often unfavourable to sub-millimetre observations during the daylight hours due to anomalous refraction[3] and cloud cover, observations are usually formally scheduled for only 16 hours per day, beginning in the late afternoon (at 1730 HST), and ending at 0930 HST each day. Temperature differentials in the antenna structure acquired during daytime observing significantly affect the telescope performance not only during the day, but also for much of the following night. For this reason, solar and other daytime observations are undertaken to a limited extent only, and on such occasions each daytime shift has been counted against the following evening shift, in order to allow the telescope time to thermally relax. This situation is being monitored to determine to what extent daytimes may be used also for commissioning and related work. When there are no other demands on the telescope, and where weather and atmospheric stability permits, it is already quite common for the night-shift observers to continue beyond 0930 HST for an hour or two.

Furthermore, as noted by Richard Wade in the *Newsletter* (March 1991), it is possible at times to continue astronomically useful observing throughout the day during periods of dry weather conditions. It is our policy to make the best use of such times, where consistent with other demands on telescope time. Observations at all frequencies can benefit from this policy. Observers should be aware then that the possibility exists for extending JCMT observing shifts in both directions (*i.e.*, starting the first shift early and extending the second shift beyond normal hours). An ongoing experiment which provides continuous Telescope Operator support at the JCMT removes some of the earlier difficulties with this mode of operations. Observers should note however that extended shift hours are not a guaranteed right; engineering and commissioning work must often be done during the day and takes precedence, so that the scheme is offered on a best-efforts basis.

2.7 Source Availability

The latitude of the JCMT allows one to observe a large fraction of the southern hemisphere, as well as all of the northern sky. In principle it is just possible to access all of the galactic plane; exceptional nights do in fact allow successful observations at very large airmasses. The trade-off, compared with northern telescopes, is that there are almost no circumpolar sources. The availability of sources as a function of declination is given below in Table 2. Note that sources between 15° and 25° declination pass very close to the zenith, and it may not be possible to

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[3] Often referred to as "bad seeing"; *i.e.* the source position appears to fluctuate by many arc seconds on timescales of tens of seconds. This is thought to be due to blobs of wet air being drawn up the mountain by convection currents. It is generally worse on summer days than winter ones. Similar effects have been observed at lower frequencies (see Altenhoff *et. al.*; 1988, *Astron. Astrophys.* **184**, 381)

observe such objects within up to 20 minutes either side of transit. In addition, because of the JCMT's location in 'Submillimeter Valley', nearby cinder cones obstruct the view of the sky at azimuths between 0° and 120°, and from 230° through to 270°, in places rising to almost 10° elevation.

Table 2: Source Availability above 20° Elevation

Declination (degrees)	Max. Elevation (degrees)	Availability (hours)	Declination (degrees)	Max. Elevation (degrees)	Availability (hours)
-60	10.2 (S)	0.0	20	89.8 (N)	10.0
-50	20.2	0.8	30	79.8	10.4
-40	30.2	5.2	40	69.8	10.6
-30	40.2	6.8	50	59.8	11.0
-20	50.2	7.8	60	49.8	11.2
-10	60.2	8.6	70	39.8	11.4
0	70.2	9.2	80	29.8	11.6
10	80.2	9.6	90	19.8	0.0

The use of Table 2, along with the approximate local sidereal time at 00^h HST as a function of date taken from the Astronomical Almanac, should allow effective planning of an observing session. An important general fact to note in this context is that the fall–winter semester is the best time to observe sources in the Orion region, while the Galactic Centre is best placed in the spring–summer semester. Unless one has an urgent and very compelling case, a proposal for sources in one of these regions in the non-favourable semester is unlikely to be scheduled. Sources in the other quadrants of the sky can be observed at some time in either semester equally well. At the end of this document (Section 8) is a chart showing the optimum month in which to observe a source, given its right ascension.

3 SPECTRAL LINE OBSERVING

3.1 General Information

Five receiver systems, covering different parts of the millimetre and submillimetre bands, will be available during during the latter part of 1991 (which includes semester 'U') for spectral line observations. Additionally, two other receivers are expected to undergo commissioning tests during this period, and *may* be available for use by observers.

Of the first five, two are 'common-user' heterodyne receivers based on cooled Schottky mixer technology; the first (Receiver A1) operates in the 220 - 275 GHz window, and the second (Receiver B2) currently from 330 to 360 GHz. These two frontends thus allow access to the J=2–1 and 3–2 CO transitions respectively. An interim SIS receiver (B3i) should also be in use on the telescope, offering a rather wider frequency coverage than B2, perhaps from 310 through to 390 GHz. A dual-channel system based on InSb 'hot electron' bolometers (Receiver C1) will be available, covering two narrow bands around the CO J=4–3 line (461 GHz) and the CI $^3P_1$–$^3P_0$ transition (492 GHz). In addition, further transitions of CO and CI at frequencies around 690 and 800 GHz, as well as other lines, are observable using the Max-Planck-Institut system ('Receiver G'), which should continue to be available through collaboration with Reinhard Genzel and his group. Receivers A2 and C2i are both SIS mixer systems which should become available to users in 1992; they are for the 230 and 490-GHz bands respectively.

3.2 Receiver and System Temperatures

For ease of reference, in Table 3 we include the approximate *best* operational parameters of the spectral line receivers available at the JCMT (or expected within the time frame of this document). Idiosyncracies of these receivers are described in the subsections below. The table gives both the double-sideband 'receiver temperature', T_{rx}, and the 'system temperature', T_{sys}. The latter is the one which must be used in the calculation of sensitivity in any given instance (see Section 3.9); this is the value typically observed at medium elevations under good sky conditions, and it includes the effects of atmospheric attenuation, and sky noise and telescope[4] contributions. T_{rx} is the noise temperature at the input port, and does not include noise contributions from outside the receiver itself. In addition T_{rx} is measured in both sidebands; in practice for spectral line observations (with the exception of receiver C1) the noise from one of the sidebands merely degrades the system performance, since the wanted line signal appears in only one sideband. The expected dates of availability to users for receivers A2, B3i, and C2i are given in the table also.

Table 3: Overview of JCMT Spectral-Line Receivers

Receiver	Type	Frequency Range (GHz)	Instant. Bandw. (MHz)	T_{rx} (K)	T_{tel} (K)	T_{sys} (K)	Beam-width (arcsec)	Mixers	Avail-ability
A1	Schottky	216 – 280	500	350	20	850	21	2	
A2	SIS	219 – 280	500	(100)	–	(300)	22	1	8/92
B2	Schottky	330 – 360	500	550	30	1600	14	2	
B3i	SIS	320 – 375	500	(200)	(45)	(700)	14	1	2/92
C1	Bolometer	461, 492	4	550	100	2900	12	2	
C2i	SIS	490±10%	1000	(500)	–	–	12	1	8/92
G	Schottky	690, 810	1000	3000	100	22000	7	2	

The various receivers for which data are available are discussed in greater detail below. Receiver B3i is included, since it has been tested on the JCMT. However, receivers A2 and C2i have yet to be completed, and will be discussed in a later section. At the time of writing they cannot be formally offered to users, and proposals may not specifically ask for them.

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[4] The quantity T_{tel} will be defined later in this document.

3.3 The Band 220 – 280 GHz: Receiver A1

3.3.1 Basics

Receiver A1 is a dual-channel device, and thus is receptive to both polarizations. However, for the most of the last three years it has been operated in a 'hybrid' mode, *i.e.* with one mixer from each frequency range. Although this mode offers flexibility with minimum risk to the equipment, observations have been possible in only one frequency band at a given time, and thus only single polarization observations could be accommodated. Recent work on the IF system at the JCMT has now made it possible for fairly routine dual polarization observations using the existing AOSC (see below) over much of the lower range of receiver A1; with a judicious choice of operating sideband and provided care is taken, calibrated observations with almost the canonical factor of $\sqrt{2}$ improvement in signal-to-noise ratio over that for a single channel can be obtained. There are no plans to allow the simultaneous observation of two lines widely spaced in frequency with the same or different receivers at this time however.

Receiver A1 nominally covers the frequency interval 220 – 280 GHz. Frequencies somewhat outside this range may be accessible with some degradation of performance. Two mixer sets are used to achieve this coverage: A1(lower) operates well up to about 250 GHz, while A1(upper) is mostly used for frequencies above about 245 GHz. An improvement in performance in the lower mixer (currently in 'channel A') has been realised recently by operating the cryostat at a slightly lower temperature. In addition tests with the upper mixer ('channel B') show that its performance is surprisingly good across the frequency range of channel A. Calibration with receiver A1 is achieved by a two-load system, one at ambient temperature, the other nominally at 66 K.

The receiver temperatures for receiver A1 as a function of observing frequency for the presently operational mixers are shown in Figure 3 and reflect the improvements made recently. Typical double-sideband receiver temperatures at the band centres are 350 K and 550 K for the lower and upper bands respectively, corresponding to single-sideband system temperatures of about 850 and 1300 K respectively in the best cases. Receiver temperatures increase with distance from the band centres; above about 270 GHz receiver temperatures are 1000 K and greater.

Using the information in this document, it is possible to derive both the system temperatures in Table 3, and any system temperature corresponding to any frequency, ν, and airmass for the purposes of calculating sensitivity. As a crude approximation, however, at medium elevations, the system temperature of Receiver A1 will be

$$T_{sys}(\nu) \sim 2.7 \times T_{rx}(\nu) \tag{1}$$

under good conditions.

3.3.2 Local Oscillator arrangement for Receiver A1

To encompass the complete frequency interval, three Gunn local oscillators are employed. These access the observing frequencies 213.6 – 248.0, 247.8 – 271.0, and 264.5 – 282.7 GHz. Changes between Gunn oscillators are normally be carried out only during the day. The Gunn oscillator frequency is tripled, and mixed with the incoming radiation to produce upper and lower sidebands centered at 3.94 GHz (the IF) above and below the local oscillator frequency. The present local

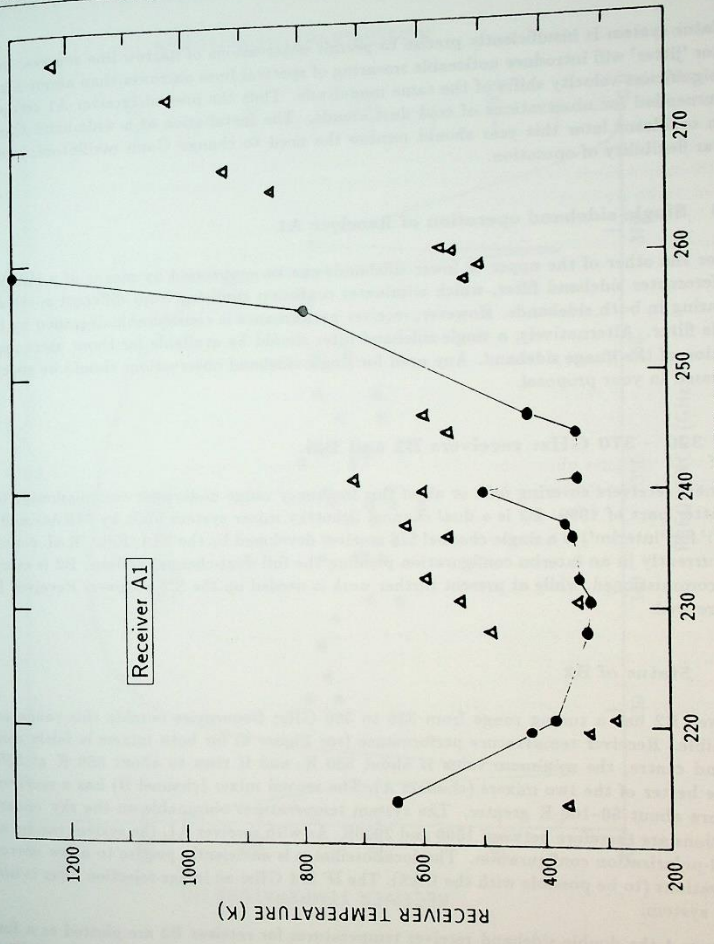

Figure 3: Double-sideband receiver temperatures (T_{rx}) for Receiver A1 as a function of observing frequency, taken from recent measurements. These data are a mixture of observations in the upper and lower sidebands. The form of the T_{rx} curve as a function of frequency results from the use of two mixers to cover the band (● = channel A; △ = channel B). Atmospheric attenuation is fairly constant across this band (see Figure 1).

oscillator system is insufficiently precise to permit observations of narrow line sources; local oscillator 'jitter' will introduce noticeable smearing of spectral lines narrower than about 1 km/sec, and significant velocity shifts of the same magnitude. Thus the present receiver A1 setup is not recommended for observations of cold dust clouds. The installation of a wide-band Carlstrom Gunn oscillator later this year should remove the need to change Gunn oscillators, and allow greater flexibility of operation.

3.3.3 Single-sideband operation of Receiver A1

One or the other of the upper or lower sidebands can be suppressed by means of a Fabry-Perot interferometer sideband filter, which eliminates confusion resulting from different spectral lines appearing in both sidebands. However, receiver performance is considerable degraded by the use of this filter. Alternatively, a single-sideband filter should be available for those users requiring rejection of the image sideband. Any need for single-sideband observations should be specifically addressed in your proposal.

3.4 320 – 370 GHz: receivers B2 and B3i.

Two new receivers covering part or all of this frequency range underwent commissioning tests in the latter part of 1990. B2 is a dual-channel Schottky mixer system built by MRAO and RAL. B3i ('i' for 'interim') is a single-channel SIS receiver developed by the HIA/Kent/RAL consortium and currently in an interim configuration pending the full dual-channel system. B2 is essentially fully commissioned, while at present further work is needed on the SIS receiver. Receiver B1 has been retired.

3.4.1 Status of B2

Receiver B2 has a tuning range from 330 to 360 GHz; frequencies outside this range are not accessible. Receiver temperature performance (see Figure 4) for both mixers is fairly constant; at band centre, the minimum value is about 550 K, and it rises to about 650 K at 330 GHz for the better of the two mixers (channel A). The second mixer (channel B) has a receiver temperature about 50–100 K greater. The system temperatures obtainable on the sky under good conditions are therefore between 1500 and 2000K. As with receiver A1, the system can be used in a dual-polarization configuration. The local oscillator is sufficiently precise to allow narrow-line observations (to be possible with the DAS). The IF is 4 GHz; an image rejection filter is included in the system.

In Figure 4 the double-sideband receiver temperatures for receiver B2 are plotted as a function of observing frequency. The system temperature of Receiver B2 is approximately related to the receiver temperature by

$$T_{sys}(\nu) \sim 3.0 \times T_{rx}(\nu)\,. \tag{2}$$

under good conditions, over essentially the whole accessible band. However, one should note (*cf.* Figures 1 and 4) that the atmosphere is much more critical in its effect on the system temperature for this frequency range.

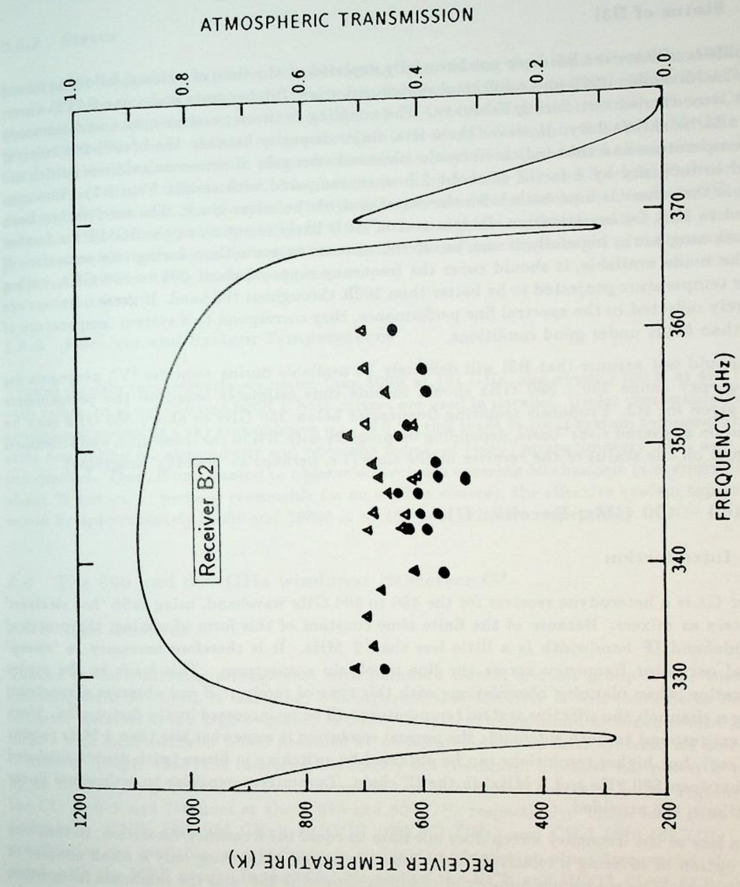

Figure 4: The double-sideband receiver temperature (T_{rx}) of receiver B2 as a function of observing frequency from recent measurements by Hugh Gibson. Two mixers are available (● = channel A; △ = channel B) and can be used in either single or dual polarization mode (with some restrictions in effect). The variation of atmospheric transmission across the band (excluding weak absorption features) is also shown for a water vapour pressure of 1mm.

3.4.2 Status of B3i

The abilities of Receiver B3i have not been fully explored at the time of writing; following mixed success in November 1990 and additional subsequent work, further tests and some PATT observations were carried out during February. The coupling between receiver optics and telescope appears to be satisfactory. However there is a major disparity between the broadband receiver noise temperature and that indicated by the observed strengths of astronomical lines (which are reduced in intensity by a factor of about 2.5 when compared with results from B2). The conclusion is that there is a problem with the mixer and/or the mixer block. The receiver has been returned to HIA for investigation. In semester 'U' it is likely to return to the JCMT for further commissioning work; hopefully it can be offered to users at some time during this semester. If it can be made available, it should cover the frequency range of about 305 to 380 GHz, with a receiver temperature projected to be better than 300K throughout the band. If these numbers are ultimately reflected in the spectral line performance, they correspond to a system temperature of better than 900K under good conditions.

Users should not assume that B3i will definitely be available during semester 'V'; proposals for the frequency range 330 - 360 GHz should include time estimates based on the performance figures given for B2. Proposals requiring frequencies below 330 GHz or above 360 GHz may be accepted on a 'shared risks' basis, depending on progress with B3i in the meantime, and scheduled contingent on the status of the receiver at the time (*i.e.* perhaps as 'standby' programs).

3.5 460 – 490 GHz; Receiver C1.

3.5.1 Introduction

Receiver C1 is a heterodyne receiver for the 450 to 500 GHz waveband, using InSb 'hot electron' bolometers as mixers. Because of the finite time constant of this form of mixing, the practical single-sideband IF bandwidth is a little less than 2 MHz. It is therefore necessary to 'sweep' the local oscillator frequency across the line to obtain a spectrum. This leads to the major consideration when planning observations with this type of receiver: if one observes a spectrum covering n channels the effective system temperature will be be increased by the factor $\sqrt{2n}$. Since the mixers respond to both sidebands the normal resolution is somewhat less than 4 MHz (about 2.6 km/sec), but higher resolutions can be obtained by switching in filters (with double-sideband widths between 500 kHz and 4 MHz) in the IF chain. Two mixers, sensitive to orthogonal linear polarizations, are provided.

The step size of the frequency sweep does not have to equal the frequency resolution, so that one has the option of covering a relatively wide frequency range while using only a small number of spectral points. The maximum number of channels allowed is 256, and the minimum integration time per channel is 10 msec.

Although the mixers and the multipliers should operate over the entire range from 450 to 500 GHz, the Gunn oscillators for the L.O. have a very limited tuning range. The present complement provides coverage *only* for the ^{12}CO J=4–3 and $^3P_1$–$^3P_0$ neutral carbon lines with two oscillators tuning to approximately 461 ± 1 GHz and 492 ± 1 GHz respectively. This has the consequence that observations of objects with radial velocities in excess of several hundred km/sec are not possible.

3.5.2 Status

Receiver C1 underwent extensive commissioning tests during June and November 1989. As a result of these tests and some additional work, Receiver C1 is now available in its final form for observations of frequencies close to the CO J=4–3 (461.04 GHz) and neutral carbon (CI) $^3P_1$–$^3P_0$ (492.16 GHz) lines. Actual ranges are ±1.0 GHz at 461 GHz and -1.0 to +0.52 GHz at 492 GHz. The standing waves which plagued the earliest observations have been eliminated and mixer improvement at 492 GHz realised. Also, recent work by Dennis Bly and Rachael Padman during January 1991 has seen the completion of the LO system and the hot load. Observers should still be aware that although the operation of C1 is now straightforward and routine, the atmosphere prevents useful observations for more than one-half of the time on average, so that one should be prepared with a suitable backup programme.

3.5.3 Receiver and System Temperatures

Typical receiver temperatures are better than 800K at 461 GHz, and about 1300 K at 492 GHz for each mixer, or about 550 and 900K if both mixers are used in parallel. Under reasonably good sky conditions (assuming a sky transmission η_{sky} of 0.2), this leads to total system temperatures T_{sys}, after accounting for atmospheric and telescope losses, of (very) approximately 3000 and 7000 K per channel. Then, if one wanted to observe a spectrum covering 50 channels (*i.e.* equivalentm to about 29 km sec^{-1}, perhaps reasonable for an outflow source), the effective system temperatures would be approximately 30000 and 70000 K at 461 and 492 GHz respectively.

3.6 The 690 and 800 GHz windows: 'Receiver G'

3.6.1 The Receiver

Thanks to the continuing arrangement with Reinhard Genzel and his group at the Institut für extraterrestrische Physik in Garching, it is expected that Receiver G will continue to be offered to users. Receiver G is a high-frequency heterodyne system using liquid nitrogen cooled Schottky mixers with local oscillator power provided by an infrared-pumped laser system. As described in *'Protostar'* (Sept. 1988) the instrument is largely self-contained. Because LO power is provided by an IR laser, only certain discrete frequencies can be accessed, currently in the regions around the CO J=6–5 and 7–6 lines at about 690 and 800 GHz respectively. Three laser lines are used commonly: $^{15}NH_3$ (802.986 GHz), HCOOH (692.951 GHz) and CH_3I (670.463 GHz). Other possibilities are available, and individuals wishing to observe at other frequencies should first check with the MPE group. In the 800 GHz region, the HCN and HCO^+ (J=9–8) lines can be observed, along with the neutral carbon ($^3P_2$–$^3P_1$) transition. It is useful to note that the J=6–5 transition of CO is much easier to detect than the CO(7–6) line, since the telescope is considerably more efficient at the lower frequency. In general the IF bandwidth is about 1 GHz, with coverage in the IF between 1 and 10 GHz, with some gaps. Further technical details can be found in Harris et. al. (1987)[5]. Receiver G comes with its own on-board acousto-optical spectrometer system; see Section 3.7.

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[5] *Int. J. Infrared and Millimeter Waves*, **8**, 857

3.6.2 Status

Since July 1989 Receiver G has been mounted on the right Nasmyth platform of the JCMT. Typical double sideband receiver temperatures range from 3000 through 4500 K; specifically, at CO(6–5) and ^{13}CO(6–5) receiver temperatures of 3000 and 3500 K are obtained. The resulting single-sideband system temperatures are extremely sensitive to atmospheric conditions, but are likely to be of the order of 50000 K or more, under practical conditions. It is likely that a period of up to one month in each semester will continue to be set aside specifically for observations with Receiver G; interested users should develop proposals with this in mind, and be aware that a low-frequency back-up proposal requesting no time (*Protostar*, Sept. 1989, p. 12) is also required, so that useful observations can be made even when weather conditions no longer permit high-frequency observations.

Individuals interested in using Receiver G should contact either Prof. R. Genzel or Dr. A. Harris for further information and to arrange collaborative efforts. The address is: Max-Planck-Institut für Physik und Astrophysik, D-8046 Garching bei München, West Germany. Electronic mail can be sent to Dr. Harris at `harris@dgampe5d.bitnet`. Because of the extremely specialized nature of the receiver, it is necessary to have the experts present during the observations, and collaboration is the best way to arrange this.

3.7 Spectrometer Backends

By the end of 1991 an autocorrelation spectrometer should be available at the JCMT for users of receivers A and B in their various versions. An acousto-optical spectrometer will also be available in case of technical problems with the former. The MPE receiver 'G' has its own spectrometer. The properties of the spectrometers are summarized in Table 4, and some additional notes are given below.

As a guide, 1 MHz is equivalent to 1.30 km/s at 230 GHz,
0.87 km/s at 345 GHz,
0.65 km/s at 461 GHz,
0.43 km/s at 690 GHz,
and 0.37 km/s at 810 GHz.

As explained above, receiver C1 is a narrow-band bolometer device, and consequently does not employ a spectrometer.

3.7.1 'Dutch' Autocorrelation Spectrometer (DAS)

The DAS employs a 3-level (2-bit) sampling logic and has 2048 delay channels. It consists of 16 analogue sections each 125 MHz wide. In its initial configuration, these are to be divided equally between two 1-GHz-wide IF inputs (and thus allows 'dual-channel' observations[6]); it can accept up to eight IF inputs when receivers requiring this capability become available. The DAS will be configurable to allow up to 8 frequency sections (one for each analogue section) per IF input, with channel separations ranging from 16 kHz through 1 MHz. Band-limiting filters will be switched in for the narrow bands (less than 125 MHz) to prevent aliasing. Initially it is expected that the DAS will be available only in the configurations given in Table 4. Eventually, however, it will be configurable in a wide variety of bandwidth/resolution combinations, in which the analogue sections can also be offset in frequency from one another.

Table 4: Spectrometer Parameters

Device	Configuration	Bandwidth (MHz)	No. of Sections	Ch. spacing (kHz)	Resolution (kHz)	Chan. per section
DAS*	A0	1000	1	1000	1200	1024
	A1	500	1	500	600	1024
	A2	250	1	250	300	1024
	A3	125	1	125	150	1024
	A4	62	1	62	75	1024
	A5	31	1	31	37	1024
	A6	16	1	16	19	1024
AOSC	—	500	1	250	330	2048
MPE('G')	—	1100	1	~500	~1000	2048

* All numbers refer to one of the two available sections only

The DAS is currently being completed in Dwingeloo. Delivery in Hilo is expected by fall 1991 and it should be working and available to users of the JCMT by late in the year.

3.7.2 The 'Canadian' acousto-optical spectrometer (AOSC)

The AOSC has a single available bandwidth of 500 MHz (see Table 4). At 230 and 345 GHz this is equivalent to 652 and 435 km/s respectively. This imposes some restrictions on the total width of lines which can be reliably observed, and has ramifications especially for extragalactic work; observing a broad line in overlapping adjacent spectral windows is in principle a possibility, but the user should be aware that this can lead to unreliable results, due to baselevel and calibration uncertainties. Furthermore, the AOSC is not useful for sources in which fine velocity detail is expected, or projects in which small velocity differences are important. Dual polarization observations are possible with the AOSC; in this mode the available bandwidth per IF channel is reduced to somewhat less than half the total. From 1992 on, the chief function of the AOSC is to be a back-up to the DAS. Russell Redman (HIA, Ottawa) has produced a detailed document for anyone who would like to know more about the AOSC; copies are available either from him or from the JAC in Hilo, and are available to observers at the JCMT site.

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[6] That is, for receivers having two independent mixers, such as A1 and B2 at present, signals from both may be received simultaneously and combined in data reduction.

3.7.3 The MPE acousto-optical spectrometer (MPE-AOSC)

The MPE receiver 'G' has its own AOS on-board. The approximate parameters of this are given in Table 4. Further details of this type of AOS may be found in Scheider *et. al.* (1989).[7]

3.8 Observing Techniques with Heterodyne Receivers

Spectral line observations can be made using either by *position-switching* or *beamswitching*. Frequency-switching is not a practical method at present, because of hardware limitations.

In *position switching* the telescope observes alternately the source and a nearby reference position, from which pair of spectra the software obtains a calibrated result from which most instrumental and atmospheric effects have been eliminated. The integration time spent on a single signal or reference position is a compromise between observing efficiency and the rapidity with which conditions change, but is typically 30 seconds or less. Some improvement in observing efficiency for mapping observations can be obtained by specifying that several signal spectra be taken for a single reference spectrum. The efficacy of this approach will depend on the level of receiver and sky stability. If baseline ripples are found to be a problem (rarely the case), then users may wish to experiment with modifying the focus position by a suitable fraction of a wavelength between subscans; most ripples appear to be the result of cable flexures and will therefore not be improved by focus modulation however.

Beamswitched observations are made using the chopping secondary mirror. In this technique, the secondary mirror is 'chopped' (usually at 1 Hz, and usually in the azimuth direction, although chopping in any direction is possible) with the source in one beam. At a slower rate, typically every 10 – 30 seconds, the telescope is moved by an amount equal to the chop throw, to bring the source into the other beam. Thus a negative line signal is obtained when the source is in the reference beam, and a positive one when it is in the signal beam. Both signal and reference phases are necessary; if one attempts to omit the reference part of the cycle, standing waves are the likely result. For receiver G observations the beamswitching method is *de rigeur*, since better elimination of sky variations is obtained. Generally the technique is effective for sources of small angular size (*i.e.* smaller than the beam throw — see section 2.5 for limits on this), and should produce better results whenever sky noise is a problem (most of the time).

3.9 Estimating Time Requirements and Sensitivity for Heterodyne Receivers

For position- (or beam-) switched observations, the rms value of the temperature fluctuations observed in a spectrum, expressed in Kelvin, is given by the expression:

$$T_A^*(rms) = (2.0 \times T_{sys} \times \kappa)/\sqrt{t \times B} \qquad (3)$$

The 'antenna temperature' T_A^* is that actually measured at the telescope, and in order to convert this to the internationally accepted T_r^* scale, it will be necessary to make a further correction:

$$T_r^*(rms) = T_A^*(rms)/\eta_{fss} \qquad (4)$$

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[7] Scheider, R., Tolls, V., Winnewisser, G.; 1989, *Experimental Astronomy* **1**, 101

The equivalent flux density sensitivity in Janskys (applicable to point sources) is:

$$S(rms) = 15.6 \times T_A^*(rms)/\eta_a \qquad (5)$$

In these expressions, the various parameters have the following meanings:

- The backend degradation factor, κ.

  This allows for the inherent inefficiency in the detection of signals by the spectrometer. For an acousto-optical spectrometer (*e.g.* AOSC; see Section 3.7) $\kappa = 1$, whereas for a 2-bit digital correlator, such as the DAS $\kappa = 1.15$.

- The total integration time, t, in seconds.

  This includes the time spent on the reference position, but not telescope movement time etc, when the backend system is not integrating. At present, since equal times are spent on the signal and reference positions, only $t/2$ seconds are spent actually integrating on the source position.

- The noise bandwidth, B, in Hz.

  This is the effective frequency resolution of each channel in the spectrometer backend. It is *not* the same as the channel spacing; the normal minimum resolutions are given in Table 4; if you intend to smooth your spectra to some greater effective channel bandwidth, it is the latter value you should use in eqn. 3.

- The system noise temperature, T_{sys}, in Kelvin.

  Approximate values for the system temperatures of receivers A1 and B1 are given in Table 3. This is the effective single sideband noise temperature of the receiver taking into account the losses in the receiver, atmosphere and telescope, and the fact that a spectral line is observed in only one of the two sidebands. The system temperature is calculated from the relation:

  $$T_{sys} = 2 \times [T_{rx} + T_{sky} + T_{tel}]/[\eta_{sky} \times \eta_{tel}] \qquad (6)$$

  where the factor 2 comes from the assumption (sometimes quite approximate) that the receiver has the same equivalent noise temperature in both sidebands[8]. In eqn. 6:

  T_{rx} is the double sideband receiver noise temperature (the number usually quoted by the builders of the receiver — see also Tables 3 and 5);

  T_{sky} and T_{tel} are the additional noise contributions from the sky and telescope respectively;

  η_{sky} is the fraction of radiation transmitted by the atmosphere at the zenith angle (Z) in question. This is a strong function of frequency (see Figure 1), and depends on the pathlength through the atmosphere (more precisely, on the 'airmass', A). The transmission at the zenith, $\eta_{sky,zen}$, is related to the optical depth at the zenith (τ_{zen}) by:

  $$\eta_{sky,zen} = \exp[-\tau_{zen}] \qquad (7)$$

  and hence the transmission at airmass A is

  $$\eta_{sky,A} = \exp[-\tau_{zen} \times A] \qquad (8)$$

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[8] For Receiver C1 (see Section 3.5), this factor is 1.0, since both sidebands cover the same frequency range

or approximately

$$\eta_{sky,Z} = \exp[-\tau_{zen} \times \sec(Z)] \tag{9}$$

In practice the sky contribution is derived by measuring the emission from the sky and then using

$$\eta_{sky} = 1 - T_{sky}/T_M \tag{10}$$

where T_M is the mean physical temperature of the atmosphere, typically 260 K.

η_{tel} is the receptive efficiency of the telescope after accounting for ohmic losses and spillover. Currently, this parameter is being re-determined, and since it is higher than originally thought, is the subject of ongoing efforts. As indicated in Table 3 one should probably use T_{tel} = 30 K for receivers A1 and B1, and 100 K for receiver C1 in the meantime, corresponding to η_{tel} = 0.89 and 0.63, respectively.

- The forward spillover and scattering efficiency, η_{fss}; beam efficiency η_B

  This is a measure of what fraction of the forward antenna pattern is coupled to an extended source. That is, it is a correction for the radiation scattered from large angles by spill-over past the subreflector, scattering by the support legs, etc. It is conventional to define η_{fss} as the coupling to a source of 0.5° diameter, so that it can be measured by observing the Moon. The quantity 'beam efficiency' (η_B; see also Section 2.6.1) is not as extensively used in millimetre and sub-millimetre astronomy[9]. Approximate values of η_{fss} and η_B are given in Table 1, where these have been determined.

- The aperture efficiency, η_a

  This factor (see Table 1) defines the response of the telescope to a point source of radiation; it is the ratio of the strength of the signal actually received to that which would have been received by a 'perfect' telescope of the same diameter, *i.e.* a telescope with no losses or blockage, having uniform illumination and no surface errors.

Hence, in order to calculate the time required for a given observation, one must first decide on the frequency resolution required by the measurement and the rms sensitivity in Kelvins T_r^* (or flux density). T_{sys} can be taken from Table 3, and the backend degradation factor κ from the notes above. The inversion of eqn. 3 then leads to the total integration time, t, for the observation alone (*i.e.*, with no overhead for telescope movement, pointing, calibration and set-up of equipment).

3.9.1 Examples: Approximate rms sensitivities after 30 minutes' integration.

In Table 5 I give examples of the calculated rms noise $T_A^*(rms)$ in Kelvin after a total observation time of 30 minutes (this assumes 15 minutes on source, 15 minutes on a reference position), for three different values of the atmospheric transmission. There have been requests to provide a tabulation of measured results obtained during actual observing runs. Unfortunately, the tabulation would then neither be complete nor consistent, since the available information has been taken under a wide range of conditions. However, it is my experience that the values listed represent what is actually observed. It is also my experience that the rms noise decreases as the square root of the total integration time except in pathological cases. The rms noise values also scale directly with system temperature, and thus are critically dependent on atmospheric conditions. The system temperatures and rms noise quoted should be achieved under 'typical' conditions (approximately 1.5mm of water vapour), and will rise rapidly as the weather worsens. In parentheses, the expected values of the rms noise are given for 'exceptional' and 'poor' weather conditions (about 0.5 and 5 mm of water vapour respectively). Although these numbers should be taken as a guide only, it is clear immediately from this table that atmospheric conditions affect receiver B2, C1 and G observations strongly, and poor conditions (as indicated by asterisks) render work at the higher frequencies impossible. One should always have a contingency plan, in case of uncooperative weather. Observations are almost always possible at 230 GHz.

Table 5: Rms noise values for selected frequencies after 30 minutes' integration

Frequency (GHz)	Receiver System	T_{rx} (K)	T_{sys} (K)	Resolution (MHz)	$T_A^*(rms)$ (K)	Notes
230	A1	350	960	0.33	0.08 (0.07, 0.11)	1
270	A1	1000	2700	0.33	0.22 (0.19, 0.30)	
330	B2	680	2140	0.33	0.18 (0.16, 0.67)	1
345	B2	560	1720	0.33	0.14 (0.12, 0.32)	1
461	C1	560	30800	4.00	0.72 (0.41, *)	2,3
492	C1	900	76000	4.00	1.79 (1.25, *)	2,3
690	G	3000	43800	1.00	2.28 (0.97, *)	3
810	G	4000	78800	1.00	3.71 (1.43, *)	3

Notes:
(1) Single channel operation assumed; dual channel possible.
(2) This assumes a total of 50 channels in the spectrum and dual-channel operation.
(3) A '*' indicates that observations are impossible when conditions are 'poor'.

3.10 Estimating Overheads for Spectral Line Observations

The actual elapsed time for any given observations will of course be greater, due to operational overheads, which depend on the observing technique and hardware used. In general one can expect to spend of the order of 10–25% more time in telescope movement and software overheads.

3.10.1 Allowing for Receiver Tuning Time

The user may find it useful to have practical estimates of the time required to both set up and tune each of these receivers; if frequent retuning is expected during a program, allowance should be made for this in estimating the total time for the program. Assuming that the requested receiver is cooled and operational in the required frequency band, initial startup by the observatory staff usually takes no more than one half-hour; retuning the receiver within the available frequency range often can be carried out within 5–15 minutes. However, installation and cooling from warmed-up state takes considerably longer, of course, of the order of a day or two, so that the use of a particular receiver has to be planned well in advance. It should be noted that the upper

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[9] See Kraus (1966, 1986) for a discussion of beam efficiency.

and lower bands of Receiver A1 correspond to physically different local oscillators at present, and hence observations requiring both high and low observing frequencies cannot usually be carried out during the same observing day. Prospective users should therefore ensure that their instrumentation requirements are clearly set out in their proposals.

3.10.2 Pointing and Calibration

The frequency with which pointing observations should be performed during an observing run depends primarily on the beamwidth (frequency) in use and the type of observation being carried out. The fraction of time spent in this exercise increases dramatically at the higher frequencies. Calibrations will also be required more often at higher frequencies, during less stable atmospheric conditions, and for sources at low elevations. As a rough practical guide, one should dedicate about 10–20% of the total observing time to these activities at the lower frequencies, and about 40% at the higher frequencies, where UKT14 is used most of the time to monitor pointing, and extra time is required to switch between it and the spectral line receiver being used.

4 OBSERVING CONTINUUM SOURCES: UKT14

The UKT14 bolometer system[10] provides the submillimetre continuum capability of the JCMT. It is mounted at the left Nasmyth focus of the JCMT. The bolometer detector is cooled to 0.36 K using pumped liquid ^{3}He as the primary, and liquid ^{4}He and nitrogen as secondary, coolants. Mean operational times between necessary coolant replacements are 40 to 48 hours or more. The input radiation from the antenna optical system is coupled to the detector by means of a hyperbolic tertiary mirror, a cooled Fabry lens, and a parabolic horn.

4.1 Aperture, Beamwidth and Efficiencies

Unlike heterodyne detectors which can accept only a single 'mode' from the telescope, a bolometer can absorb multiple modes. At the diffraction limit both polarizations are normally received while at the shorter wavelengths at full aperture (A), many spatial modes can be accepted, proportional to $(A/\lambda)^2$. The aperture is controlled by a variable iris at the input to the dewar and a Fabry optical system. For an extended source using a large aperture will give more signal. However it will also bring in more noise not related to the source since the source is coupled to one mode, whereas the background is coupled to all modes. This has the effect of reducing the apparent efficiency of the telescope at a given frequency relative to that obtained for heterodyne receivers. For small sources, and to obtain high angular resolution, one should use a smaller aperture, as determined by the diffraction limit.

The maximum aperture size, as set by the lens, is 65mm, and this corresponds to a beamwidth of about 20 arcsec. For wavelengths longward of 1100μm (1.1mm) this results in less than optimum coupling to the beam pattern of the JCMT, and correspondingly reduced aperture efficiencies. The diffraction-limited aperture size can be chosen for wavelengths shorter than 1100 μm, as indicated in Table 6. However, because of the non-ideal beam pattern at the higher frequencies,

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[10] See W.D. Duncan *et. al.* *M. N. R. A. S.* **243**, 126 (1990)

the limited accuracy to which the telescope can be pointed, and the lack of accurate calibration information for the smaller apertures, we do not currently recommend using apertures less than about 47mm for photometric observations unless special efforts at calibration are anticipated. At all the higher frequencies this results in an effective 'beamwidth' of about 15 arcsec. Mapping[11] and skydip observations on the other hand are usually made with an aperture matched to the diffraction-limited beam; in this case allowance should be made in the proposal for making beam maps of planets to aid in the interpretation of the data.

A number of filters allow the user to select a waveband of interest. Switching between filters (and adjusting the lens aperture) is straightforward and automated. The filters have a range of characteristics, which are described in Table 6. The 850 and 750-μm filters are specially designed to avoid the stronger telluric lines in the 800-μm window, and thus to reduce calibration uncertainties. The previously-available ultra-wideband 1-mm filter has been retired.

Table 6: UKT14 Filter Band Properties and Sensitivities

Filter (mm)	Wave-length (μm)	Centre Freq. (GHz)	Band-width (GHz)	Aper-ture (mm)	Beam-width (arcsec)	NEFD (65mm ap.) Jy.Hz$^{-1/2}$	Notes
2.0	2000	150	40	65	28	2.0 (2.0, 3.0)	1
1.3	1300	233	64	65	21	0.3 (0.3, 0.5)	
1.1	1100	264	75	65	19	0.3 (0.3, 0.7)	
0.85	850	354	30	47	16	0.8 (0.7, 5.0)	
0.8	761	394	103	47	14	0.7 (0.5, 5.0)	
0.75	730	411	28	47	14	0.9 (0.7, 5.0)	2
0.6	625	480	119	36	9	—	3
0.45	438	685	84	27	7	6.0 (4.0, *)	4
0.35	345	870	249	21	6	12.0 (8.0, *)	4

Notes:

(1) At this wavelength the UKT14 optics is poorly coupled to the JCMT.

(2) Not yet commissioned fully. Values will be somewhat greater than for the 0.85-mm filter.

(3) This filter is best avoided. It is difficult to obtain consistent calibrations, due to deep atmospheric absorption lines in the band.

(4) A '*' indicates that observations are impossible when conditions are 'poor'.

In Table 6 the centre frequency is not equal to the effective frequency, since the effective frequency is influenced by frequency-dependent variables such as the atmospheric transmission, and antenna efficiency, whereas the centre frequency is simply defined to be the average of the frequencies at which the filter response is 50% of its maximum. The filter width is the frequency interval between these two 50% frequencies. The profiles of most of the filters are shown in Figure 5.

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[11] See Göran Sandell's article in the March 1991 *Newsletter* for an introduction to practical submillimetre-wavelength map-making with the JCMT

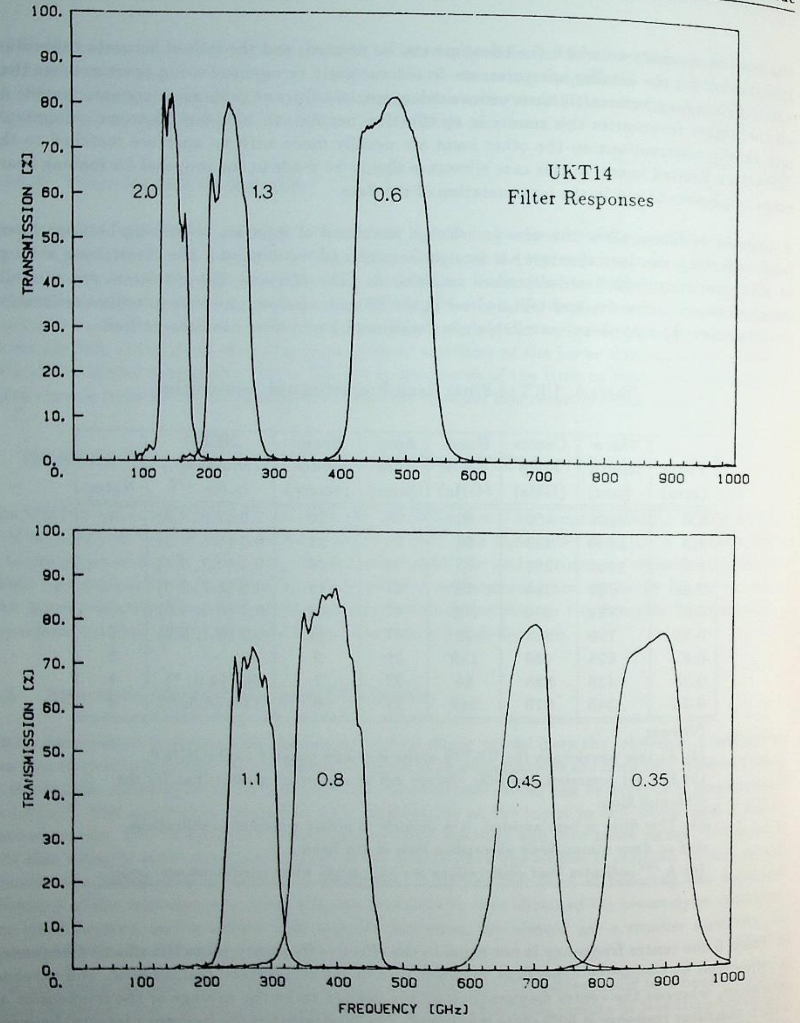

Figure 5: Response functions for each of the filters used for observations with the continuum bolometer system UKT14. The 850- and 750-μm filter responses were not available when this document was prepared.

4.2 Sensitivity and Integration Time

The approximate sensitivity (NEFD = noise equivalent flux density) is given in terms of the rms value in Janskys for a one-second integration; in other words, if you integrate for t seconds, and the NEFD is F, the resultant rms noise will be about $F/\sqrt{t}$. Alternatively, if you require an rms sensitivity of S Jy, you will have to integrate for something like $(F/S)^2$ seconds.

The value of the NEFD ranges from typically 0.3 Jy/sqrt(Hz) at the longer wavelengths (with the exception of the 2mm band, which is poorly matched to the antenna), through to 10 Jy/sqrt(Hz) or more at the highest frequencies under good photometric conditions. In Table 6 three values of the NEFD are given: the first is that which should be obtained under 'good' conditions for a 65mm aperture (as normally used for photometry); users should use this in estimating time requirements. In parentheses, values for the 'best' and 'poor' atmospheric conditions are given, simply to indicate typical ranges obtained. At the shorter wavelengths observations are impossible under 'poor' conditions; the apparent NEFD is replaced with an asterisk in such cases in Table 6. For the purpose of writing proposals, it is appropriate to choose an NEFD corresponding to "good" conditions, rather than "best". On average, this ensures that your time estimates will be reasonable.

Incidentally, one might assume that one should simply integrate continously with UKT14 until the desired signal-to-noise ratio is attained. This is not the case. The dominant contribution to the noise in a UKT14 measurement originates from the atmosphere. It is not just the transmission and thermal emission of the atmosphere which influences the signal/noise ratio, but the major effect is correlated noise due to atmospheric microstructure. The degree of atmospheric instability is reflected in the integration time beyond which the signal/noise ratio does not improve according to gaussian statistics. Furthermore atmospheric stability does not appear to be correlated with improved transmission, but rather the converse. Thus it is difficult to provide further guidance to the user on the effect of differing atmospheric conditions. What is usually done to combat this effect is combine a number of short (say 5 minutes each) measurements, rather than one longer one, and derive the mean flux density and internal standard deviation from the set of signals. The length of each integration will be judged from the atmospheric conditions at the time of the observations.

4.3 Observing Techniques

Observations with UKT14 are almost always performed using the chopping secondary mirror. The properties of this are described in Section 2.5 above. Its use eliminates a large proportion of the sky noise variations which are a fact of life at submillimetre wavelengths. Photometry is performed by alternately placing the source in the signal and reference beam of the chop cycle ('beam-switching'). Typically the chop frequency is 7.8125 Hz, and the chop throw 60″. Generally, the smaller the chop throw, the better the results. Maps can be made point-by-point or 'on-the-fly'; the latter much more efficiently uses telescope time than the former, particularly for anything but the smallest maps. Map data are processed with the NOD2 package (Section 6.3), which has the necessary tools to perform most operations including the deconvolution of maps taken in the beam-switched mode.

4.4 Calibration

Calibration at sub-mm wavelengths is extremely important to obtain reliable results. However, it is difficult and special care must be taken. The prime calibration source is Mars, but Venus, Jupiter, Saturn, Uranus (preferably) and Neptune can also be used, although Jupiter and Saturn (and sometimes Venus and Mars) require substantial flux corrections for beamsize. If none of these planets is available, compact HII regions and planetary nebulæ can be used. A program is ongoing to establish a set of secondary calibrators. Also, a chopper-wheel calibration unit (consisting of four sectors; two open, and one each presenting an ambient and a cold load) is permanently installed just in front of the UKT14 cryostat window. This is used routinely to perform sky brightness measurements, usually 'skydips', from which the atmospheric transmission is derived. A large database of such measurements is currently being established to relate models of the atmosphere to water vapour content. From these data it expected to be possible to provide reliable measures of the sky opacity.

4.5 Pointing and Overheads

Prospective users should ensure that sufficient time is allowed in their proposal for UKT14 observations for thorough pointing and focus measurements, as well as calibration (the latter is useless without the former). It may be necessary to check both the signal and reference beams to verify beam response equality, and to check that the beam chopping is behaving as expected. A list of pointing sources is available, including the planets, planetary nebulæ, compact HII regions, and quasars, and continues to be improved.

In making continuum photometry and mapping observations, the careful observer will spend a significant amount of time in frequent calibration measurements. This time is to be added to the 25% or so which should ordinarily be added to allow for telescope movement and so forth. The actual 'astronomical' overhead will depend on the program goals, observing techniques, and source strengths, and may range from about 20% extra up to 80% or more in the most extreme cases. In estimating this overhead, one may conclude that mapping programs tend to consume the lowest overheads, while photometry of strong sources result in high overheads. Higher-frequency observations demand greater overheads, because of the need to carry out more frequent pointing and calibration checks.

4.6 Polarimeter for use with UKT14

The Aberdeen/QMW rotating quartz waveplate polarimeter is available as an optional accessory for the UKT14 bolometer system. It may be used in step and integrate mode only (*i.e.*, photometry is performed at each of a number of waveplate position angles). It can be used at 1100, 800 and 450μm. Some of the first observations with the polarimeter have been published recently.[12]. The instrumental polarization is 1–2% at 1100μm, <1% at 800μm, and ~3% at 450μm. Most of the latter appears to be due to the JCMT membrane (wind blind).

The effective NEFD of the polarimeter/UKT14 combination is NEFD(p) = 2×NEFD/P, where P is the degree of polarization of the source. The additional factor of 2 arises because one polarization only is detected. Thus, for example, the detection of the polarized signal from a 20% polarized source will take $(2/0.2)^2$ (= 100) times longer than the detection of the unpolarized object using UKT14 alone. In addition, in order to measure the Stokes' parameters of a source, several (say, at least 4) sets of photometry at different angles are needed. Aside from this, polarimeter observations are subject also to all the problems resulting from atmospheric noise that afflict UKT14 measurements.

4.7 Continuum observations with heterodyne receivers

There is presently no separate backend for continuum observations with the heterodyne receivers.[13] Pointing and focus observations are usually made using the chopping secondary mirror and the UKT14 backend electronics and software. However, it should be noted that heterodyne receivers are substantially less sensitive than UKT14 in this mode at an equivalent wavelength. For instance, Receiver A1, in single polarization, double sideband mode, is 2–3 times less sensitive than UKT14, depending on the water vapour content of the atmosphere. This need not be a disadvantage; in particular, solar observations do not require great sensitivity and can be performed using receiver B2.

Mapping observations are usually made in an 'on-the-fly' mode, rather than point-by-point. For such observations, as for UKT14, the data are now sampled by a microcomputer in one of the IF sections after synchronous detection.

5 THE FUTURE

A number of programs are under way at the various institutes either to build specific equipment for the JCMT or to carry out research and development intended to lead to such equipment. Facilities which are expected to become available to the user as a result of these programs, and which will be of particular interest to the potential user are described below. Projected dates for the arrival in Hawaii and eventual availability to the user are given; it hardly need be said that these dates can be considerably in error due to currently unforeseen technical (and other) problems. An official announcement is made, normally in the *Newsletter*, as each becomes available for use by the astronomical community.

5.1 Receiver A2

As indicated in Table 3, a lead-alloy SIS junction receiver (A2) should be commissioned during semester 'V'. The specifications call for a double-sideband receiver temperature of 100K or less throughout a tuning range of 219 to 280 GHz. Under typical conditions one might therefore expect a total system temperature of about 400K (SSB). Once A2 has completed commissioning on the telescope early in 1992, it will likely be available on a 'best efforts' basis to users during the remainder of semester 'V'. However, specific requests for its use should not be made until its availability is announced in the *Newsletter*, and no firm values for its performance can be quoted at this stage.

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[12] See A.M. Flett, A.G. Murray; *M. N. R. A. S.* **249**, 4P (1991)

[13] A 'universal' continuum backend is under construction and is likely to be in use by the end of 1991.

5.2 Receiver C2i

C2(i) ('i' for 'interim') is a single-channel SIS receiver for the 461/492 GHz band currently under construction at RAL. It is expected to be commissioned at the JCMT during 1992. A recent report[14] indicates excellent progress and a ±10% tuning range centered on 490 GHz (*cf.* Table 3). The IF bandwidth is expected to be about 1 GHz. Few predictions can be made for the performance of this receiver at present, however it is likely to have a receiver temperature of the order of perhaps 500K (DSB). As is the case for receiver A2, proposals cannot be accepted for C2(i) until it has been commissioned, but if it were available at the time of observations, proposals for C1 could make use of it.

5.3 *SCUBA*

SCUBA (*S*ubmillimetre *C*ommon-*U*ser *B*olometer *A*rray) is a submillimetre camera being built at the Royal Observatory Edinburgh for use on the JCMT[15]. Delivery is expected around August 1992. It has two arrays, each with a field of view of roughly 2.5 arcmins; one array operates at 850 or 750μm and the other at 450 or 350μm. In additional there will be individual detectors to allow observations at $\lambda\lambda$1.1, 1.3 and 2.0mm. All detectors will be cooled to about 0.1 K by a ^{3}He/^{4}He dilution refrigerator. The instrument will be mounted on the left-hand Nasmyth platform of the JCMT currently occupied by the UKT14 bolometer system. Because the detectors (131 in all) will be much more ($\sim$ 10 times) sensitive than those in UKT14, *SCUBA* will be able to acquire data thousands of times faster than UKT14, and will consolidate the position of the JCMT as the world's premier submm continuum telescope. The first prototype bolometric detectors have been manufactured to the necessary specifications, and production versions are under construction. The transputer-based data acquisition electronics is also well advanced. Delivery to Hawaii is currently expected to take place around the end of 1992.

6 DATA HANDLING

6.1 Data Archive and Export

Local staff archive telescope data as a matter of routine, and currently undertake to store[16] the data indefinitely, although a firm policy on access rights and lifetime for the archived material still has yet to be established. The information is currently available to the original investigators only, and copies (but not the originals) can be made on request. The JCMT stores data on-line using the Global Section Datafile (GSD) format. The observatory can provide backup of these data files either in binary or as ASCII copies on 1600 or 6250 bpi 9-track tapes (but not TK50 or TK70, unless you bring your own). FITS format tapes are available upon request (NRAO ASCII tables extension FITS only at present; the new binary tables scheme agreed to recently in Green Bank is still being discussed, and we are likely to be able to offer CLASS-compatible FITS at some time). Observers should discuss their requirements with the local staff before the export tapes are written. Users may also be able to transmit their data electronically to sites outside the island of Hawaii; depending on the speed of transmission this can be economical.

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[14] Internal progress report by B.N. Ellison, March 1991

[15] These notes are based on a recent report by Walter Gear (*Newsletter*, March 1991, page 15).

[16] Presently on both magnetic tape and optical disc.

6.2 SPECX

Spectral line data are stored on disk as the observations progress, and can be accessed immediately by the observer using the spectral line data reduction package SPECX, written by Rachael Padman. This package (now available in version 6.0) offers a quite complete set of facilities for averaging spectra, fitting baselines, and other forms of data manipulation. It is especially powerful at handling map data. The same package exists at the Hilo headquarters, and users are invited to make use of this facility at the conclusion of their observing run. SPECX is available also on the STARLINK network for off-line data analysis in the U.K. Other facilities, such as DRAWSPEC (made available by Harvey Liszt at NRAO, Charlottesville) and PCPOPS (from Ron Maddalena, NRAO Green Bank) are being developed for use on PC-compatibles. We plan to install CLASS and IRAF for those who may need them.

6.3 NOD2

Analysis of continuum map and skydip data obtained from the UKT14 bolometer receiver is performed using the NOD2 package[17]. This is a subroutine library for the general manipulation of radio single-dish observations. The package was initially developed at the Max-Planck-Institut für Radioastronomie, Bonn; the version used at the JCMT and in Hilo is essentially identical to that in use at NRAO, Kitt Peak, and has been kindly made available by Darrel Emerson. NOD2 is also available on the STARLINK network. Some of the functionality of NOD2 is being absorbed into the STARLINK-developed FIGARO package.

7 SUBMITTING PROPOSALS

Applications for observing time on the JCMT should be submitted to the Panel for the Allocation of Telescope Time (PATT). The applications are considered by an international panel of astronomers and judged in terms of their scientific merit. Demand exceeds available time (currently by a factor of between 2 and 3), and not all proposals can be granted time.

7.1 Application Procedure

PATT operates on a cycle of six months' duration[18]. Each year is divided into two semesters: 1 August to January 31 and 1 February to 31 July. The panel convenes twice annually in order to allocate time for the following semester. Semesters are labelled alphabetically. Proposals are given code numbers of the form *Mxnnn*, where *'M'* stands for 'Maxwell', *'x'* will be the semester character, and *'nnn'* is a number.

The closing dates for receipt of applications are:

31 March	(for following August – January)
30 September	(for following February – July)

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[17] Haslam, C.G.T., 1974, *Astron. Astrophys. Suppl.*, **15**, 333. Data reduced using this package should acknowledge the fact by quoting this reference.

[18] There has been a one-month shift in the semester pattern to accommodate the AAT. To effect this change semester U will cover only 5 months (September 1991 to January 1992).

A proposal for use of the JCMT necessarily consists of (i) a completed application form and (ii) a written justification for the observations proposed (one page of the form is provided for this). A copy of the application form (PATT 3) is appended to this document. It is to your advantage to fill it in to the best of your ability, and with the maximum clarity; a better-prepared proposal always stands a better chance of success than one sloppily presented. There is a pamphlet (PATT 5) called 'Notes for Guidance . . .' (which is also appended to original copies of this document, or which can be obtained from the PATT), which can be consulted in cases of doubt.

Completed application forms (note: **ten** copies of each!) should be sent to:

The Executive Secretary
Panel for the Allocation of Telescope Time
Science and Engineering Research Council
Polaris House
North Star Avenue
Swindon SN2 1ET
United Kingdom

7.2 Things to Note

A few additional remarks concerning applications for telescope time should be made:

1. Because of the shift structure of the schedule at the JCMT, safety concerns and the need to keep vehicle movements as efficient as possible, observers should request an integral number of 8-hour shifts (evening and/or morning) in their time estimate. Shifts cannot be split between two programs, unless of course the same investigators are involved in both programs. The current shifts are 1730-0130 (evening) and 0130-0930 (morning) HST. Observers should be careful to specify in their proposal if one or other shift is preferred, or alternatively, whether both are equally usable. Item (8) on the form should contain this information; note that the sidereal time interval is also required (item 11). Observers should be aware also of the possibility of extended operating hours, and 'flexible scheduling' as mentioned above, and in the *Newsletter*[19].

2. Entry (9) on PATT-3 requests a list of principal targets; in order for the PATT and local (Hawaii) staff to assess potential conflicts with other programs, it is recommended that all objects to be observed be included. In this context, it is worth noting that there is a strong likelihood that your favourite source may well have set, or not yet risen, during part of your scheduled time, especially in view of the 8-hour 'granularity' mentioned above. Against such eventualities, one should have a stated contingency plan, in the form of *e.g.*, another program, or additional sources of relevance to the program. For low declination sources, this may be essential (see Table 2), even if the preferred dates given in Item (5) are permitted by the pressure of scheduling.

3. Again in the interests of minimizing conflicts between observing programs, it is strongly preferred that proposers have a concrete back-up program (item 7) in the event of equipment failure (or inconsiderate weather conditions); such a program preferably should be submitted to, and approved by, the PATT.

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[19] March 1991 issue; pp. 8 and 9

An entire page is reserved on the PATT form for the scientific case. In making this case, a number of things should be borne in mind. PATT-5 tells you some of them. In addition, the basic requirements are of course good science and technical feasibility. It is hoped that if there are any questions regarding the latter, this document will have helped. In respect of the former, one might read "Tips for your JCMT Proposal", by Lorne Avery and John MacLeod (*Protostar*, September 1987).

The PATT is also quite strict about the format of the scientific case presented with the PATT form. The current rules are that the text should not cover more than one side of A4 (or $8 \times 10''$) paper with typescript, singly spaced. The typeface should be no more than 12 characters per inch (Elite), with a maximum of 6 lines per inch (*i.e.*, normal typewriter spacing). TEX and LATEX output also appears to be acceptable. However, avoid ever-decreasing font sizes and overly-crammed pages; photo-reduction is also a no-no!

Two further pages may be added to the scientific justification if desired; the first of these should contain technical justifications only, and the second diagrams and references. This approach serves to reduce eye- and nerve-strain on the part of referees and assessors, who have to read many proposals. Further material (such as preprints; *three* copies of each) may be added for the education of the referee(s) and assessors, if desired, but given the pressure of the refereeing tasks this may not benefit your case; better to be succinct.

Additional copies of the PATT application form and "Notes for Guidance . . ." are available from the Hawaii Telescopes Unit at the Royal Observatory Edinburgh, the Joint Astronomy Centre in Hilo, or from PATT at SERC in Swindon (addresses below). In Canada[20] forms may also be obtained from:

JCMT Unit
Herzberg Institute of Astrophysics
100 Sussex Drive
Ottawa
Ontario K1A 0R6
(Tel: 613-993-6060; Telex 053-3715 nrc ott)

and in The Netherlands from:

NFRA
Radiosterrenwacht Dwingeloo
7990 AA Dwingeloo
(Tel: 05219-7244; Telex 42043 srzm nl)

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[20] Les Scientifiques Canadiens qui préfèrent présenter leur application au PATT en Français doivent la faire parvenir au Bureau du Directeur, l'Institut d'Astrophysique Herzberg, 100 Prom. Sussex, Ottawa, Ontario K1A 0R6. Les applications qui necessitent être traduites doivent être reçues au Bureau du Directeur 21 jours avant la date de fermeture du semestre voulu. L'application seras traduite á l'anglais et les deux versions seront ensuite transmises directement au PATT.

7.2.1 Long-Term Proposals

With one exception (other than your proposal arriving after the deadline), proposals will not be held over from one semester to the next; unsuccessful proposals should be resubmitted with complete justification. The one exception is that a proposal may request *long-term status*; time can then be granted for a number of semesters conditional on continued success. Only certain types of proposal merit this kind of status; the case is judged by two referees (as opposed to the usual one). If the proposal is not considered to merit long-term status, it is then treated in the normal way for regular proposals. Only one long-term proposal has been active in recent semesters.

7.2.2 User-supplied equipment

Proposals which require the installation of user-supplied equipment will be considered on a basis separate from those for commissioned equipment; anyone contemplating such a venture should first contact the JCMT Director (Richard Wade) for further discussions.

7.2.3 Canadian Service Observing

Canadian observers may apply for service observing. This is an experimental program the continuation of which is likely to depend on demand. In semester 'T' two shifts were allocated for such observations. The intention of service programs is that short observations (requiring not longer than four hours) may be requested, in order to *e.g.* complete an existing data set, obtain some crucial data, or test an hypothesis. The observations will be carried out by HIA staff while they are at the JCMT. Proposals should be sent to Paul Feldman at HIA (Ottawa) by electronic mail at `jcmtserv@hiaras.hia.nrc.ca` (InterNet) or by confidential fax to (613)-952-0974. Information regarding proposal deadlines, dates, and equipment available are distributed via the JCMT electronic listserver; additional information can be obtained by contacting `jcmtserv` or Paul Feldman directly. To get on the listserver mailing list contact Russell Redman at `redman@hiaras.hia.nrc.ca`.

7.3 Scheduling

Successful applicants are informed of the allocation made to them by the Executive Secretary, PATT. Scheduling of the telescope time is carried out in Hawaii. As far as possible this is arranged to take into account the preferred dates indicated in the application. It is necessary, however, to avoid an excessive number of instrument changes in the interests of efficiency and limiting potential for damage to the equipment. Changes in preferred dates may be taken into account if they are transmitted to the Associate Director for the JCMT (Richard Wade) or Graeme Watt as soon as possible after an allocation meeting. Where conflicts arise, attempts should be made to resolve them by telephone, fax, or electronic mail.

The eventual dates scheduled for their observations are communicated to the successful applicants about four weeks after the allocation meeting (*i.e.* in total, about three months after the submission deadline). It is the responsibility of the Principal Investigator to provide the necessary information to his/her collaborators. At this time you will be reminded of the need to provide the necessary health certification for work at altitude, and of the regulations for the use of Observatory vehicles and so forth. Principal Investigators must inform the Associate Director for the JCMT through Donna DeLorm at the Joint Astronomy Centre in Hawaii of the names of observers and the dates of arrival at least 3 weeks before the run. Because of limited space in the Observatory dormitory (at Hale Pohaku) usually not more than three observers can be accommodated on the mountain at any one time. There are also safety limits which *require* the presence of at least two investigators if a shift is to be longer than 14 hours.

Unsuccessful applicants will be informed of the reasons for the rejection of their proposal, and should consider re-submission of a revised proposal if it is feasible with the equipment available.

7.4 A Disclaimer

This document has outlined equipment which should be commissioned and in service on the telescope during the coming semester and offers a forward look for new facilities which are planned in the relatively near term (see Section 5 above). Because of the uncertainties involved, no promises are intended to be implied thereby, and proposals requesting the use of facilities which are unavailable by the time of the PATT meeting most likely will have to be resubmitted. Time lost due to weather, receiver or telescope malfunction is rarely compensated for (and even then only for time lost arising from problems which could have been prevented) because of the stringent constraints on available telescope time; a new proposal for further observations should be submitted at the proper time to the PATT.

7.5 Final Remarks

When scheduling observing time on the telescope the object of the Observatory is to achieve as nearly as practically possible the scientific program approved by PATT. It is important to recognize that observing time is awarded for specific programmes and does not 'belong' to applicants to use as they wish. Because of the considerable potential for conflict with the programs of other users, substitutions or additional observations must be cleared with the JCMT Director.

Each successful program will have the services of a support scientist (although not necessarily at the telescope) and a telescope operator throughout the allotted time, and every effort will be made to ensure that the best possible results are achieved. Once granted time, the principal investigator should ensure that as much has been done in the way of preparations for the program as possible; observers are encouraged to contact their support scientist at this point. Except in cases where the support scientist or telescope operator is a co-investigator, the JCMT staff do not undertake to carry out absentee (service) observing, or provide data reduction services. In-house JCMT staff can often be persuaded to adopt co-investigator status however. It is strongly suggested that scheduled users plan to arrive at least one day early in order to discuss their project with their assigned support scientist and other local experts. In addition, it is often useful to remain after an observing session to provide feedback to local staff, and perhaps even give an informal talk at the Joint Astronomy Centre.

Remote operations have recently been demonstrated to be viable with the JCMT; it is possible for an observer possessing a VT series or Tektronix-emulating terminal to remotely log in to the

JCMT computers and 'eavesdrop' on the operations and data reduction. This system does not permit remote *control* of the telescope, but it opens up the possibility for the active and real-time participation of collaborators unable to make it to the telescope site or Hawaii. It is still necessary for at least one member of an observing team to be present on site however.

7.6 Contacting JCMT Personnel

Local Headquarters:

Joint Astronomy Centre	Telephone	808-961 3756 or 808-935 5207 (Hilo)
665 Komohana Street		808-935 7606/9911 (Hale Pohaku)
Hilo		808-935 0852 (summit)
Hawaii 96720	Fax	808-961 6516
U.S.A.		808-935 5493 (summit)
	Electronic mail	{*userid*}`@jach.hawaii.edu` (InterNet)

Anyone mentioned as local contact persons above may be reached at the above address. So may, in addition, the Director of the Joint Astronomy Centre (Dr. M.G. Smith; `mgs`), the Associate Director for the JCMT (Dr. R. Wade; `wade`), the JCMT support group (Drs. F. Baas (`baas`), I.M. Coulson (`imc`), W.R.F. Dent (`dent`), W.D. Duncan (`william`), P. Friberg (`friberg`), H.E.Matthews (`hem`), G. Sandell (`sandell`), and G.D. Watt (`gdw`, PATT technical secretary)), and all other JAC personnel. For electronic mail, replace {*userid*} by the user identification of the person you want to contact; usernames are given in parentheses with each name.

U.K. Headquarters:

JCMT Section	Telephone	(0)31-668-8100
Hawaii Telescopes Unit	Fax	(0)31-668-8264
Royal Observatory	Electronic mail	{*userid*}`@uk.ac.roe.starlink` (JANet)
Blackford Hill		
Edinburgh EH9 3HJ		
Scotland U.K.		

Amongst the individuals the user may wish to contact at the Royal Observatory are Perry Williams (`pmw`, head of the JCMT section), Alex McLachlan (`aml`), and Liz Sim (`mes`), the latter for matters relating to the *Newsletter*.

Canadian and Dutch contacts can also be reached by electronic mail. Personnel at the JCMT Unit of the Herzberg Institute of Astrophyics can be reached at {*userid*}`@hiaras.hia.nrc.ca` (InterNet); for example users may wish to contact John MacLeod (`johnm`, head of the JCMT Unit), Lorne Avery (`lorne`), Paul Feldman (`paf`), or Russell Redman (`redman`). In The Netherlands one can reach NFRA personnel at {*userid*}`@nfra.nl`; *userid* for Wilf Boland is `boland` and for Wim Brouw `wnb`.

8 WHEN TO OBSERVE?

This table[21] shows in which month one should observe such that a source at a given right ascension transits at a given (local Hawaiian) time. Upper case indicates spring/summer semester (February through July), lower case for fall/winter (August through January) semester.

```
         |--- FIRST SHIFT ---|-- SECOND SHIFT ---|
HST 16   18   20   22   24   02   04   06   08   10   12   14 (local time)
RA  |----|----|----|----|----|----|----|----|----|----|----|----|--|  RA
24 -               |                        |                      - 24
  | Jan  Dec  Nov  Oct  Sep  Aug  JUL  JUN  MAY  APR  MAR  FEB     |
22 -               |                        |                      - 22
  | Dec  Nov  Oct  Sep  Aug  JUL  JUN  MAY  APR  MAR  FEB  Jan     |
20 -               |                        |                      - 20
  | Nov  Oct  Sep  Aug  JUL  JUN  MAY  APR  MAR  FEB  Jan  Dec     |
18 -               |                        |                      - 18
  | Oct  Sep  Aug  JUL  JUN  MAY  APR  MAR  FEB  Jan  Dec  Nov     |
16 -               |                        |                      - 16
  | Sep  Aug  JUL  JUN  MAY  APR  MAR  FEB  Jan  Dec  Nov  Oct     |
14 -               |                        |                      - 14
  | Aug  JUL  JUN  MAY  APR  MAR  FEB  Jan  Dec  Nov  Oct  Sep     |
12 -               |                        |                      - 12
  | JUL  JUN  MAY  APR  MAR  FEB  Jan  Dec  Nov  Oct  Sep  Aug     |
10 -               |                        |                      - 10
  | JUN  MAY  APR  MAR  FEB  Jan  Dec  Nov  Oct  Sep  Aug  JUL     |
08 -               |                        |                      - 08
  | MAY  APR  MAR  FEB  Jan  Dec  Nov  Oct  Sep  Aug  JUL  JUN     |
06 -               |                        |                      - 06
  | APR  MAR  FEB  Jan  Dec  Nov  Oct  Sep  Aug  JUL  JUN  MAY     |
04 -               |                        |                      - 04
  | MAR  FEB  Jan  Dec  Nov  Oct  Sep  Aug  JUL  JUN  MAY  APR     |
02 -               |                        |                      - 02
  | FEB  Jan  Dec  Nov  Oct  Sep  Aug  JUL  JUN  MAY  APR  MAR     |
00 -               |                        |                      - 00
RA  |----|----|----|----|----|----|----|----|----|----|----|----|--|  RA
HST 16   18   20   22   24   02   04   06   08   10   12   14
         |--- FIRST SHIFT ---|-- SECOND SHIFT ---|
```

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[21] Original by R.E. Hills

9 FURTHER READING

JCMT general

Introductory Information for Visitors to the Joint Astronomy Center; available from the Royal Observatory Edinburgh

PATT Newsletter; issued by SERC

The JCMT-UKIRT Newsletter, published by the Royal Observatory Edinburgh

Introduction to mm- and sub-mm astronomy

Th. de Graauw; 1982, coordinator, Workshop on *The Scientific Importance of Submillimetre Observations*, ESA Publication SP-189

J.M. Payne; 1989, *Proc. I.E.E.E.* **77**, 993

P.A. Shaver and K. Kjär; 1985, editors, ESO-IRAM-Onsala Workshop on *(Sub)millimeter Astronomy*, ESO Conference and Workshop Proceedings No. 22

G.D. Watt, A.S. Webster; 1990, editors, *"Submillimetre Astronomy"*, Astrophysics and Space Science Library, **151**, Kluwer Academic Publishers

G. Winnewisser, J.T. Armstrong; 1989, editors, *"The Physics and Chemistry of Interstellar Molecular Clouds"*, Lecture Notes in Physics, **331**, Springer-Verlag

R.D. Wolstencroft, W.B. Burton; 1988, editors, *Millimetre and Submillimetre Astronomy*, Astrophys. Space Science Library, **147**

Antenna theory

J.D. Kraus; *Radio Astronomy*, First Edition: McGraw-Hill, 1966; Second Edition: Cygnus-Quasar Books (Powell, Ohio), 1986

Mauna Kea/Hawaii

D.P. Cruikshank; *Mauna Kea - A Guide to the Upper Slopes and Observatories*, University of Hawaii, Institute for Astronomy, 1986 (additional references therein)

Dept. of Geography, University of Hawaii; *Atlas of Hawaii*, University of Hawaii Press, Honolulu, 1979

Altitude effects (physiology etc.)

C.S. Houston; *Going Higher*, Little, Brown and Co. (Boston, Toronto), Third ed., 1987

Calibration of mm/sub-mm data

B.L. Ulich, R.W. Haas; 1976, *Astrophys. J. Suppl.* **30**, 247

M.L. Kutner, B.L.Ulich; 1981, *Astrophys. J.* **250**, 341

M.L. Kutner, L. Mundy, R.J. Howard; 1984, *Astrophys. J.* **283**, 890

Attached to original copies of this document:

PATT application form (PATT 3)
"Notes for Guidance . . ." (PATT 5)

PATT 3
Millimetre &
Submillimetre

SCIENCE AND ENGINEERING RESEARCH COUNCIL
POLARIS HOUSE, NORTH STAR AVENUE, SWINDON SN2 1ET
Telephone 0793 411000 Telex 449466 Fax 0793 411348

JAMES CLERK MAXWELL TELESCOPE
APPLICATION FOR TELESCOPE TIME

For Office use only
REF:-

READ 'NOTES FOR GUIDANCE PRINT ENTRIES IN BLUE OR BLACK

SEMESTER

2 i) Principal applicant: Possible observer
Surname Title Initials Y/N

Institution . . . . Department . . . . Post . . . .

ii) Principal observer (if different) Y/N

iii) Collaborators (state institution)
Y/N
Y/N
Y/N

iv) Principal contact: Telephone & Ext.
Address Fax
Telex
E. Mail

3 TITLE OF INVESTIGATION (12 WORDS MAXIMUM)

4 SCIENTIFIC CATEGORY ☐ Solar System ☐ Stellar ☐ Galactic & Interstellar ☐ Extragalactic & Cosmology ☐ Other

5 LONG TERM STATUS: Y/N
If yes total number of useful nights/weeks needed to complete programme
HIGH FREQUENCY: Y/N

6 ABSTRACT OF PROPOSED OBSERVATIONS

7 ABSTRACT OF BACK UP PROGRAMME FOR POOR OBSERVING CONDITIONS

8 DETAILS OF OBSERVING TIME, INSTRUMENTS ETC FOR THIS SEMESTER
NB. If own instrument, not previously used on telescope, attach a concise description on a separate page

Shifts (8 hours)	Frontend (see users manual)	Observing Frequencies (molecule/transition)	Sources

i) Preferred dates . . . .
ii) Impossible dates (give reason) . . . .

9 LIST OF PRINCIPAL SOURCES

Name	RA (hh mm)	Dec (dd)	Brightness/Flux (T_r^*(K)/F(mJy))	V(lsr) (km/s)	Linewidth (km/s)	Notes priority

10 BREAKDOWN OF TIME REQUESTED

a) Line observations

Receiver(s) ....

Backend ....

Rest freq (GHz)	Req sensitivity (rms; K)	Freq resolution (MHz)	Total number of spatial points	Total time (hrs) (incl overheads)

b) Continuum observations

Receiver ....

Filter (microns)	Aperture (arcsec)	Req sensitivity (mJy)	Total number of spatial points	Total time (hrs) (incl overheads)

c) Other requirements (own instrument, polarisation, etc.)

11 OBSERVING

Sidereal time interval ....

Observing support required ....

12

(i) Have applications for observing time time on other telescopes/satellites for this or similar programmes in the coming semester been made YES/NO

(ii) If YES state:
- a) Telescope/satellite ....
- b) Title of programme ....
- c) Whether simultaneous observations required YES/NO

13 RELATED APPLICATION/PUBLICATIONS

(i) Related PATT applications over last 4 semesters (include unsuccessful applications)

Semester/Year	Telescope	Ref	Request	Allocated	Clear nights	Comments

(ii) Title and reference of all publications (incl. preprints) over last 4 semesters which have resulted from PATT time.

(iii) Other publications relevant to this application

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(i) Are the observations primarily for a student research training programme? YES/NO

If YES, state
- a) Name of student(s) ....
- b) Project title(s) ....
- c) SERC studentship no(s) (UK only) ....

(ii) Are the observations associated with a current research grant? YES/NO

If YES, state
- a) Name of principal investigator ....
- b) Grant number ....

15

Indicate experience of intended observers who have not previously used this telescope

16 FUNDING

(i)

Name	No. of nights	Reason (data reduction, etc.)	Funding Source SERC/NRC/ASTRON/OTHER

(ii) Please indicate any other anticipated expenditure (freight, remote observations etc.)

17 SCIENTIFIC JUSTIFICATION

(Case NOT to exceed this A4 page. One side of diagrams references may be attached if desired).

AUTHORISATION (UK observers only)

We have read the 'Notes for Guidance' relating to applications to the Panel for the Allocation of Telescope Time and if an award is made, understand that all participants may be required to sign a form of indemnity before being permitted to use the equipment. We are not bound by any contrary conditions governing the proposed investigation including obligations to third parties incurred in respect of ownership and use of research results and patents.

	Signature	Date
Principal Applicant		
Principal Observer		
Head of Applicant's Department/Establishment		
Administrative Authority (State position held)		

SUBMISSION OF APPLICATIONS

The original typed copy of the completed application form and scientific case for support, together with EIGHT copies of each and at least THREE copies of any supplementary material, should be despatched to reach the council by the appropriate closing date (see below) and should be addressed to:-

The Executive Secretary,
Panel for the Allocation of Telescope Time,
Science and Engineering Research Council,
Polaris House, North Star Avenue,
SWINDON SN2 1ET U.K.

CLOSING DATES

SEMESTER:	Applications must be received on or before:
August-January	31 March
February-July	30 September

TO BE COMPLETED BY THE APPLICANT

INVESTIGATOR(S) DEPT(S)/ INSTITUTION(S)/T&S REQUIREMENT	SHORT TITLE OF INVESTIGATIONS	COMMENTS AND SCHEDULING PREF.	NO. OF SHIFTS (8 HOURS)	
			REQUESTED	MINIMUM

ADDRESS FOR ACKNOWLEDGEMENT

SCIENCE AND ENGINEERING RESEARCH COUNCIL
POLARIS HOUSE,
NORTH STAR AVENUE,
SWINDON SN2 1ET

We acknowledge receipt of your application form dated please quote reference / / in future correspondence.

JCMT_PATT_NOTES 21-Nov-1989 (Expiry: 30-Nov-1989)

SCIENCE AND ENGINEERING RESEARCH COUNCIL PATT 5
Panel for the Allocation of Telescope Time (PATT)
Millimetre and Submillimetre

NOTES FOR GUIDANCE on the completion of the application form (PATT 3) for observing time on the James Clerk Maxwell Telescope.

PATT is responsible for the allocation of observing time on the James Clerk Maxwell Telescope (JCMT) in Hawaii.

From time to time the availability of facilities may change; any changes will be announced in Protostar and the PATT Newsletter both of which are available from this office.

APPLICATIONS FOR OBSERVING TIME

PATT, which is an advisory body to the SERC's Astronomy and Planetary Science Board, is composed of working astronomers, mainly from academic institutions but with some government establishment representative, who are appointed for a period of 3 years. There are also certain members appointed by the Netherlands Canada and Ireland. Staff astronomers from the Royal Greenwich Observatory, Royal Observatory Edinburgh and Anglo-Australian Observatory are routinely present at each meeting to advise on allocating and scheduling on the JCMT and other SERC supported telescopes.

In awarding time PATT looks primarily at the scientific merit and timeliness of the proposals, having regard both to their feasibility and, where appropriate, to the record of the proposers in making use of previous allocations.

PATT meets every six months, in January and July, and divides into four Time Allocation Groups (TAGs) which allocate time on their respective telescope(s) AAT, ING, UKIRT and James Clerk Maxwell Telescope (JCMT).

Applications must be made on the official PATT application form for the relevant telescope (PATT 2 or PATT 3) and will be accepted any time during the six months prior to the closing date for each semester. These closing dates are shown below and are the latest dates when applications for that semester will be considered by PATT. Applicants, and in particular overseas applicants, are advised to post their applications in sufficient time to meet these dates, having regard to any particular local postal problems. Applications received after the relevant closing date will be held over to the next PATT meeting.

Semester	Closing date
March - August	31 October
September - February	30 April

COMPLETION OF THE APPLICATION FORM

A separate application form must be completed for each observing programme and for each telescope, even if the same programme is proposed.

Section 1: Applicants should indicate the semester in which they require time. Semesters are indicated by letters consecutively, e.g. September 89 - February 90 = Semester Q.

Section 2: Should identify as the Principal Applicant (PA) a single individual. The PA in a UK application should be someone who satisfies the conditions for an SERC research grant; i.e. be a member of the permanent staff of an educational or research institution or an SERC Fellow. The PA, the nominated "principal contact" or the principal observer, will be contacted by the office and assessors as necessary during consideration of the application. The electronic mail address together with the normal address details must be included in section 2(iv). Those applicants thought likely to participate in the observing run should be identified, as a general rule no more than two applicants (excluding inexperienced students) will be supported for an eight hour observing run, three in the case of two contiguous eight hour runs and more if the applicants own equipment is being used.

Section 3: The brief title (12 words maximum) should clearly identify the specific proposed investigation.

Section 4: Applicants are asked to indicate the scientific category into which their proposal falls.

Section 5: Applicants should indicate whether or not they wish their proposal to be considered for long term status, i.e. is the programme one which is likely to require time over several semesters and if so how many useful nights/weeks will be needed to complete the programme.

High frequency status i.e. greater than 450GHz should also be indicated. A full back-up programme must be presented with such a proposal, which can be carried out in conditions which prevent high frequency observing.

Section 6: This enables applicants to provide a short description of their intended research; this should be a distillation of the essential features of the scientific case for support, which should be given in full at paragraph 17.

Section 7: Investigators are required to give a short abstract of an alternative programme which they would propose to carry out should poor observing conditions or other unexpected problems make it impossible to run the main programme.

Section 8: Observing time is allocated in shifts of 8 hours. Applicants should also specify the frontend required, observing frequencies and sources.

Applicants should also complete the sections on preferred dates and impossible nights for the observing. Every effort will be made by schedulers to meet these preferences but no guarantees can be given. It is imperative that all impossible nights in the semester are listed and reasons given. For this purpose an impossible night is one which is astronomically impossible. Teaching and other similar commitments do not count as impossible nights.

Section 9: Details of the principal targets referred to in the scientific case for support must be included here.

Section 10: Applicants should give a detailed breakdown of their request categories. Those with their own instruments should contact the Astronomer-in-Charge well in advance of the PATT meeting to determine the compatibility of the instrument and telescope.

Section 11: Observing details should be given including any request for scientific support at the telescope.

Section 12: Applicants must list all other applications for observing time on other telescopes/satellites for the same or similar programmes in the coming semester and indicate whether or not s1multaneous observations are requested. It is not sufficient to write "Known to PATT" in this section.

Section 13: Applicants should list (on a separate page if necessary) their applications which were submitted to PATT for any of the previous four semesters and which relate to the present proposal. Include all successful and unsuccessful applications which involved the present Principal Applicant as Principal Applicant or as a named collaborator. Give a list of all publications arising (first author and reference) based on usage of PATT telescopes during the same interval which include the present Principal Applicant as an author. In this case, list the papers irrespective of whether or not they are related to the present application. Other publications relevant to the present proposal should also be listed, but distinguished from those based on PATT-allocated time.

Section 14: Applicants should indicate whether the observations are primarily for a student research training programme and give the relevant details as requested. SERC research grant funds are not awarded in support of SERC students. For such students, support should be sought from SERC Studentship Section using form S102 in addition to the PATT form. Support will normally only be provided for those SERC research students who have been identified clearly on the PATT application form. Other research students should apply to their funding body for support. If the observations are associated with a current research grant, details of this should also be given (including the reference number).

Section 15: Details of experience should be given here for anyone identified in Section 2 as a possible observer who has not used the telescope in question.

Section 16: Details of all anticipated expenditure should be given and the funding source identified. Note that PATT funds cannot be used to purchase data storage tapes.

Section 17: This section should contain the scientific justification of the proposed investigation in standard typescript within the maximum of the one side of A4 provided. One separate side of A4 paper containing diagrams and/or references may be attached to the application form if desired. If the scientific justification exceeds one page, only the first page will be copied to the Panel. Further information such as preprints and supplementary material may be provided but will ONLY be made available to referees and assessors at the discretion of SERC and only provided sufficient copies (at least 3) are supplied. The information provided must be sufficiently self-contained to enable PATT to assess the scientific merit of the proposal without reference to other material. It should include a description of the overall aims of the research, the order of importance or objectives, and explanation of any unusual methods or techniques, details of scientific results achieved from previous time allocations and the relationship of these results and related work elsewhere to the current work of the applicants. Applicants should give further details of the observations to be carried out in this investigation as specified in section 8; remembering that time is more likely to be awarded if it is possible to observe the programme working at a reasonable altitude throughout the whole night in several months of the semester than if it can only be observed during one month of the semester. Brief details of the research experience of collaborators should also be given.

Authorisation: All application forms must be authorised by the appropriate university/institute authorities before they can be accepted for consideration by PATT. The authorisation also signifies acceptance that observers may be required to sign a form of Indemnity before they undertake their observing programme.

Summary Slip: All applicants are required to complete the summary slip on the title of their application and the number of shifts sought. A space is allowed for comments and scheduling preferences. Applicants are also required to fill in the acknowledgement slip which will normally be returned by the office within 7 days to indicate that the application form has been received.

OTHER POINTS TO NOTE

a. **Principal Applicants:** The Science and Engineering Research Council requires that all holders of SERC Research Grants should be permanent members of the staff of UK universities and similar educational establishments or SERC Research Fellows. The PA on a UK proposal must fulfil these requirements and thus be able to hold the relevant research grant to cover the costs associated with take up of the award of observing time. Where a student is the principal author of a proposal his supervisor should be named on the application form as PA. If observing time is allocated by PATT the PA will be sent an 'eight point questionnaire' in respect of funding required to undertake the observing programme.

b. **Resident Staff:** At many of the SERC telescope sites resident staff may be available to collaborate and assist in observing programmes. Allowance should be made for this in assessing the numbers of UK observers to be supported by SERC. Only the minimum necessary number of observers should be included in any application.

c. **Changes to Proposed Programmes:** Any requests or enquiries about making changes to proposed programmes approved by PATT which arise before the observing trip should be addressed to the Executive Secretary, PATT, and not to the PATT Chairman or individual members of the Panel. If the investigators have already arrived at the observing site, when a problem arises then it is the responsibility of the Astronomer-in-Charge to decide whether or not the changes are permissible.

COMPLETED APPLICATION FORMS

The completed application form and scientific case for support, together with EIGHT copies of each and at least THREE copies of any supplementary material e.g. pre-prints, should be sent to:

The Executive Secretary, Panel for the Allocation of Telescope Time,
Science and Engineering Research Council
Polaris House, North Star Avenue,
SWINDON, Wiltshire SN2 lET, U.K.

APPLICATIONS FOR TIME ON NON-SERC TELESCOPES

PATT considers requests from UK university based personnel, including students, for travel and subsistence, to take up time awarded on non-SERC telescopes. Application to PATT for such support should be made on form RG2, or, in the case of SERC research students, form S102 and must be sent to the Executive Secretary, PATT (RG2). or SERC Studentship Section (S102) at the same time that application is made to the non-SERC telescope. A copy of the scientific case submitted to the non-SERC telescope should accompany the application. An explanation of the travel and subsistence funds requested should also be included.

PATTI/JS1